British Association for the Advancement of Science,

BURLINGTON HOUSE,

LONDON, W.

Jan. 11, 1906.

Dear Sir,

The 1904 Report was published on the 18th of May 1905. Many of the Reports & Papers are really published (although not in our volume) when they are read at the Annual Meeting.

Yours faithfully,

H. C. Stewardson.

W. T. Calman, Esq.

REPORT

OF THE

SEVENTY-FOURTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

CAMBRIDGE IN AUGUST 1904.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1905.

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[*An asterisk * indicates that the title only is given. The mark † indicates the same, but with a reference to the Journal or Newspaper in which it is published* in extenso.]

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SUB-SECTION OF ASTRONOMY AND COSMICAL PHYSICS.

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OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Members and Associates will be entitled to receive the annual volume of Reports, *gratis,* or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.

2. *At reduced or Members' Price,* viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain,* at 2*s.* 6*d.* per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

[1] A few complete sets, 1831 to 1874 are on sale at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee not less than two years in advance [1]; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Constitution of the Sectional Committees.[3]

(i) The President, Vice-Presidents, and Secretaries of a Section are appointed by the Council in November or December. They form, with the existing members (see (ii) and (vi)), the Committee, which has the duty of obtaining information upon the Memoirs and Reports likely to be submitted to the Section at the next meeting, of preparing a report thereon, of generally organising the business of the Section, and of bringing before the Council any points which they think deserving of consideration [4]

[1] Revised by the General Committee, Liverpool, 1896.
[2] Revised, Montreal, 1884.
[3] Adopted by the General Committee at Cambridge, 1904.
[4] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which

(ii) The Sectional Presidents of former years are *ex-officio* members of these Committees.

(iii) The Sectional Committees may hold such meetings as they think proper for the organisation of the business, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting at 2 P.M. for the appointment of additional Members and other business.

Any member who has served on the Committee in previous years, and who has intimated his intention of being present at the Meeting, is eligible for election as a Member of the Committee at its first meeting.

(iv) The Sectional Committees shall have power to add to their number from day to day during the Annual Meeting, but it is not desirable for them to be larger than is necessary for efficiency; they have also the power to elect not more than three Vice-Presidents at any time during the meeting, in addition to those appointed by the Council.

(v) The List formed during the Annual Meeting is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

(vi) Before the close of the Annual Meeting each Sectional Committee is to nominate six members of the Association to form the nucleus of the Committee for the succeeding year, and forward a list of the six names to the Assistant Secretary of the Association.

Included in the six names should be the existing President of the Section, or one of the Vice-Presidents, and one of the existing Secretaries.

It will be the duty of these Members to transact the business of the Committee until the officers of the Section for the ensuing year are appointed by the Council, and thus become the officers of the Committee (see (i)).

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday (optional), Monday, and Tuesday, for the objects stated in the Rules of the Association. The Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association

they are to be read, are now as far as possible determined by the Sectional Committees *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant Secretary *before the conclusion of the Meeting.*

and printed in the last volume of the Report. He will next proceed to read the Report of the Committee that has held office since the last Annual Meeting. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to prepare a copy of the Journal for the following day by (i) removing from the list of papers those which have been read on that day; (ii) making any needful additions to or corrections in the list of those appointed to be read on following days; (iii) revising the list of the Sectional Committee, and making any other necessary corrections, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings at each Meeting of the Committee are to be entered in the Minute-Book, and these Minutes should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings, to the Assistant Secretary of the Association.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee, and will receive, on application to the Treasurer in the Reception Room, tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Annual Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science it is expedient that all Members of the Committee should be named, and one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

It is desirable that the number of Members appointed to serve on

a Committee should be as small as is consistent with its efficient working.

A tabular list of the Committees appointed on the recommendation of each Section shall be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether or no the several Committees appointed on the recommendation of their respective Sections have presented their reports.

On the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee shall be then fixed, but the Members to serve on such Committee shall be nominated and selected by the Sectional Committee at a subsequent meeting.

Committees have power to add to their number persons, being Members of the Association, whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered on the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant Secretary of the Association for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must first be sanctioned by the Committee of that Section before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.[1]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.
5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor John Perry, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.

[1] Revised by the General Committee at Ipswich, 1895.

7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such report has been received.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of any description are requested to reserve the specimens so obtained to be dealt with by authority of the Council.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

[1] The Sectional Committee is empowered to arrange the hours of meeting of the Section and of the Sectional Committee, except for Saturday.

2 To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant Secretary.

3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Official Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

The *ex officio* members of the Committee of Recommendations are the President and Vice-Presidents of the Meeting, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and shall not be taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[1]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant Secretary.[2]

Corresponding Societies.[3]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to

[1] Passed by the General Committee at Birmingham, 1865.
[2] Passed by the General Committee at Leeds, 1890.
[3] Passed by the General Committee, 1884.

the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10.[1] The Committee of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend

[1] Revised by the General Committee, 1903.

the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

The Council shall appoint and have power to dismiss such paid officers as they may consider necessary to carry on the work of the Association, on such terms as they may from time to time determine.[1]

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [2]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers and General Secretaries and past Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

[1] Passed by the General Committee at Cambridge, 1904.

[2] Passed by the General Committee at Belfast, 1874; amended at Cambridge 1904.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of twenty-three Members of the General Committee whom they recommend for election as Members of Council. The two vacancies then remaining shall be filled by the General Committee, without nomination by the Council, at the Meeting at which the election of the other Members of the Council takes place.[1]

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

[1] Passed by the General Committee at Cambridge, 1904.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S., F.R.S.E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S., F.R.S.E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., F.R.S.E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh. The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland M.A., F.R.S., F.R.S.E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast. Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge. William Lassell, Esq., F.R.S., F.R.S.E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S., F.R.S.E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PRESIDENTS	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S., F.R.S.E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1831.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.

Presidents	Vice-Presidents	Local Secretaries
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. E. R. Wodehouse, Esq., M.P. Colonel R. P. Laurie, C.B., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. Sir James Kitson Bart., M.Inst.C.E. The Mayor of Leeds Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford The Mayor of Oxford Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.

CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, Bart., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of the Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. BRADFORD, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S. Principal N. Bodington, Litt D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett, Esq., J.P. Frederick Stevens, Esq.
PROFESSOR A. W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S. GLASGOW, September 11, 1901.	The Right Hon. the Earl of Glasgow, G.C.M.G. The Right Hon. the Lord Blythswood, LL.D., D.L. The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. Samuel Chisholm, Esq., the Hon. the Lord Provost of Glasgow Very Rev. R. Herbert Story, D.D., LL.D., Principal of the University of Glasgow Sir John Maxwell Stirling-Maxwell, Bart., M.P., D.L. Sir Andrew Noble, K.C.B., D.C.L., F.R.S. Sir Archibald Geikie, D.C.L., LL.D., F.R.S. Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S. James Parker Smith, Esq., M.P., D.L. John Inglis, Esq., LL.D. Professor John Cleland, M.D., LL.D., D.Sc., F.R.S.	Sir J. D. Marwick, LL.D., D.L., F.R.S.E. Professor John Young, M.D. Professor Magnus Maclean, D.Sc., F.R.S.E.

PROFESSOR JAMES DEWAR, M.A., LL.D., D.Sc., F.R.S. BELFAST, September 10, 1902.	His Grace the Duke of Abercorn, K.G., H.M. Lieutenant of the County of Donegal The Marquis of Londonderry, K.G., H.M. Lieutenant of the City of Belfast Sir Francis Macnaghten, Bart., H.M. Lieutenant of the County of Antrim The Right Hon. the Earl of Shaftesbury, D.L. The Right Hon. the Earl of Rosse, K.P., D.C.L., LL.D., F.R.S. The Right Hon. Thomas Sinclair, D.Lit. Sir William Quartus Ewart, Bart., M.A. The Lord Mayor of Belfast The President of Queen's College, Belfast Professor E. Ray Lankester, M.A., F.R.S. Professor Peter Redfern, M.D.	John Brown, Esq., F.R.S. Godfrey W. Ferguson, Esq. Professor Maurice FitzGerald, B.A.
SIR NORMAN LOCKYER, K.C.B., LL.D., F.R.S., Correspondant de l'Institut de France. SOUTHPORT, September 9, 1903.	The Right Hon. the Earl of Derby, K.G., G.C.B. The Right Hon. the Earl of Crawford and Balcarres, K.T., LL.D., F.R.S. The Right Hon. the Earl Spencer, K.G., LL.D., Chancellor of the Victoria University The Right Hon. the Earl of Sefton The Right Hon. the Earl of Lathom Sir Henry Roscoe, B.A., Ph.D., LL.D., D.C.L., F.R.S. Sir George A. Pilkington Alfred Hopkinson, Esq., LL.D., K.C., Vice-Chancellor of the Victoria University T. T. L. Scarisbrick, Esq., Mayor of Southport E. Marshall Hall, Esq., K.C., M.P. for Southport Charles H. B. Hesketh, Esq. Charles Scarisbrick, Esq., J.P. Charles Weld Blundell, Esq.	Harold Brodrick, Esq., M.A. J. Ernest Jarratt, Esq.
The RIGHT HON. A. J. BALFOUR, D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. CAMBRIDGE, August 17, 1904.	His Grace the Duke of Devonshire, K.G., LL.D., F.R.S., Chancellor of the University of Cambridge Alexander Peckover, Esq., LL.D., Lord Lieutenant of Cambridgeshire Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Huntingdonshire The Right Rev. the Lord Bishop of Ely, D.D. The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, D.C.L., LL.D., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. The Rev. F. H. Chase, D.D., Vice-Chancellor of the University and President of Queen's College, Cambridge The Very Rev. H. Montagu Butler, D.D., Master of Trinity Mrs. Sidgwick, Principal of Newnham College, Cambridge J. H. Chesshyre Dalton, Esq., M.D., Mayor of Cambridge Robert Stephenson, Esq., Chairman of the Cambridgeshire County Council Joseph Martin, Esq., Chairman of the Isle of Ely County Council P. H. Young, Esq., Deputy Mayor of Cambridge	S. R. Ginn, Esq., D.L. A. Hutchinson, Esq., M.A. A. C. Seward, Esq., M.A., F.R.S. S. Skinner, Esq., M.A. J. E. L. Whitehead, Esq., M.A.

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1883 Lord RAYLEIGH, F.R.S.
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1898 Prof. (Sir) A. W. RÜCKER, F.R.S.

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1898–1904 Prof. G. C. FOSTER, F.R.S.
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1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
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1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
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1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900–02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902–03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.

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1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
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1890–1902 G. GRIFFITH, Esq., M.A.
1902–04 J. G. GARSON, Esq., M.D.
1904 A. SILVA WHITE, Esq., *Assistant Secretary.*

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Date and Place	Presidents	Secretaries
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.......	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
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1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
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1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
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1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
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1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin.. ..	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
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1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
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1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.

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1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof. W. E. Ayrton, F.R.S. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford ...	Dr. J. Larmor, F.R.S.—*Dep. of Astronomy*, Dr. A. A. Common, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.
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1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A. —*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees, Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees, Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

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1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.

Date and Place	Presidents	Secretaries
1838 Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S.......	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. Y. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.

Date and Place	Presidents	Secretaries
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol......	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S............. ..	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	P. P. Bedson, H. B. Dixon, H. F. Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn.
1897 Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol......	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.

Date and Place	Presidents	Secretaries
1902. Belfast......	Prof. E. Divers, F.R.S.........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope.
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope.
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, H. Murray, H. E. Strickland, J. Scoular.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A. F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay
1849. Birmingham	Sir Charles Lyell, F.R.S.......	J. B. Jukes, Prof. Oldham, A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.

[1] Geography was constituted a separate Section, see page lxix.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins, M.A., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, F.R.S...	Prof. Harkness, E. Hull, J. W. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B., F.R.S.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.......	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.

Date and Place	Presidents	Secretaries
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff......	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.......	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol......	W. H. Hudleston, F.R.S.......	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Archibald Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S. ...	H. L. Bowman, Rev. W. L. Carter, G. W. Lamplugh, H. W. Monckton.
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.
1902. Belfast......	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton, J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton.
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. Woods.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxviii.

Date and Place	Presidents	Secretaries
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxviii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham [1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.

[1] The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W.H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.

Date and Place	Presidents	Secretaries
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S., F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[2]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[3] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.

[1] Anthropology was made a separate Section, see p. lxxv.
[2] Physiology was made a separate Section, see p. lxxvi.
[3] The title of Section D was changed to Zoology

Date and Place	Presidents	Secretaries
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson.
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson, Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson, Dr. H. W. M. Tims.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr.J.Brown, Prof. Couper, Prof. Reid

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	J. Butter, J. Fuge, R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir B. Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.	Dr. W. Roberts, Dr. Edward Smith
1862. Cambridge	G. E. Paget, M.D................	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop Oliver Pembleton, Dr. W. Turner.

[1] Sections D and E were incorporated under the name of 'Section D—Zoology. and Botany, including Physiology' (see p. lxiv). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxiv.

Date and Place	Presidents	Secretaries

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lxii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres.R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J.W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H.W. Bates, David Buxton, Albert Mott, Clements R. Markham.

Date and Place	Presidents	Secretaries
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie. E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
1900. Bradford ...	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.
1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.

Date and Place	Presidents	Secretaries
1902. Belfast ...	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm, E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport	Capt. E. W. Creak, R.N., C B., F.R.S.	E. Heawood, Dr. A. J. Herbertson. E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood, Dr. A. J. Herbertson. H. Y. Oldham, E. A. Reeves.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849 Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. P. G. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872 Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D. ...	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff. ..	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.

Date and Place	Presidents	Secretaries
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol.....	J. Bonar, M.A., LL.D.	E. Cannan, Prof. A. W. Flux, H Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D. ...	A. L. Bowley, Prof. S. J Chapman, Dr. A. Duffin
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley, Prof. S. J. Chapman, Dr. B. W. Ginsburg.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol......	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York.........	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich ...	William Cubitt, F.R.S..........	John Head, Charles Manby.
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.

Date and Place	Presidents	Secretaries
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge.	William Fairbairn, F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle .	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E..........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F Churton, H. T. Wood.
1883. Southport .	J. Brunlees, Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath	W. H. Preece, F.R S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.

Date and Place	Presidents	Secretaries
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
1900. Bradford ...	Sir Alex. R. Binnie, M.Inst. C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.
1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W.E. Dalby, W. A. Price.
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price, J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price.
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.
1898. Bristol	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.
1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.
1900. Bradford ...	Prof. John Rhys, M.A.........	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.
1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon, J. L. Myres.

Date and Place	Presidents	Secretaries
1903. Southport	Prof. J. Symington, F.R.S. ...	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres.
1904. Cambridge	H. Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool ..	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.
1901. Glasgow ...	Prof. J. G. McKendrick.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne, Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft, Prof. T. G. Brodie, Dr. L. E. Shore.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol	Prof. F. O. Bower, F.R.S. ...	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.
1900. Bradford ...	Prof. S. H. Vines, F.R.S.	A. C. Seward, H. Wager, W. West.
1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward, H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager, R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager, R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S.	Dr. F. F. Blackman, A. G. Tansley, H. Wager, T. B. Wood, R. H. Yapp.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller, R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport	Sir W de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller, Dr. C. W. Kimmins.

LIST OF EVENING DISCOURSES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.............	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.

Date and Place	Lecturer	Subject of Discourse
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S..........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.

Date and Place	Lecturer	Subject of Discourse
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ..	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.

Date and Place	Lecturer	Subject of Discourse
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto ...	Prof. W. C. Roberts-Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S.	Earthquakes and Volcanoes.
1898. Bristol	Prof. W. J. Sollas, F.R.S. ..	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet............	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.
1900. Bradford ...	Prof F. Gotch, F.R.S.	Animal Electricity.
	Prof. W. Stroud.	Range Finders.
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	F. Darwin, F.R.S.	The Movements of Plants.
1902. Belfast ...	Prof. J. J. Thomson, F.R.S....	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S....	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B....	A Journey through Africa.
1877. Plymouth...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southpor	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.

Date and Place	Lecturer	Subject of Discourse
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol	Prof. E. B. Poulton, F.R.S.	The ways in which Animals Warn their enemies and Signal to their friends.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast ...	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE CAMBRIDGE MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

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COMMITTEE OF RECOMMENDATIONS.

The President and Vice-Presidents of the Meeting ; the Presidents of former years ; the Trustees ; the General Treasurer ; the General and Assistant General Secretaries ; Prof. Horace Lamb ; Sir John Eliot ; Prof. J. J. Thomson ; Prof. Sydney Young ; Prof. W. J. Pope ; Aubrey Strahan ; G. W. Lamplugh ; Dr. J. E. Marr ; W. Bateson ; Prof. S. J. Hickson ; Dr. W. E. Hoyle ; Douglas W. Freshfield ; Dr. J. S. Keltie ; E. Heawood ; Prof. Wm. Smart ; E. W. Brabrook ; Dr. E. Cannan ; Hon. Charles A. Parsons ; Col. Crompton ; W. A. Price ; Henry Balfour ; E. S. Hartland ; J. L. Myres ; Prof. C. S. Sherrington ; Prof. Schäfer ; J. Barcroft ; Francis Darwin ; Prof. H. Marshall Ward ; H. Wager ; The Bishop of Hereford ; Prof. H. E. Armstrong ; W. M. Heller ; and Principal E. H. Griffiths.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1903-1904. RECEIPTS.

	£	s.	d.
Balance brought forward	649	1	7
Life Compositions (including Transfers)	423	0	0
New Annual Members' Subscriptions	222	0	0
Annual Subscriptions	559	0	0
Sale of Associates' Tickets	667	0	0
Sale of Ladies' Tickets	365	0	0
Sale of Publications	127	4	0
Dividend on Consols	155	2	0
Dividend on India 3 per Cents.	103	1	0
Interest on Deposit	33	3	4
Income Tax returned	47	17	4
	£3351	9	3

Investments.

	£	s.	d.
Consols	6501	10	5
India 3 per Cents.	3600	0	0
	£10,101	10	5
Sir Frederick Bramwell's Gift, 2½ per Cent. Self-cumulating Consolidated Stock	58	8	5
	£10,159	18	10

G. CAREY FOSTER, *General Treasurer.*

from July 1, 1903, to June 30, 1904. *Cr.*

1903–1904.	EXPENDITURE.	£	s.	d.
	Expenses of Southport Meeting (including Printing, Advertising, Payment of Clerks, &c., &c.)	157	10	9
	Rent and Office Expenses	86	4	2
	Salaries, &c.	527	4	6
	Printing, Binding, &c.	*262	10	7
	Repair, &c., of Banners	7	13	0
	Committee on Coast Changes	12	6	6

Payment of Grants made at Southport:

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury Lake Village	25	0	0
Anthropometric Investigation on Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0

							887	18	11
							1941	8	5
On deposit at Bradford District Bank				£1027	13	4			
Balance at Bank of England (Western Branch)	£627	11	8						
Less Cheques not presented	247	18	11						
				379	12	9			
Cash in hand				2	14	9			
							1410	0	10
							£3351	9	3

* Exclusive of an outstanding Printing Bill of about £1,000.

I have examined the above Account with the books and vouchers of the Association, and certify the same to be correct. I have also verified the balance at the Bankers', and have ascertained that the Investments are registered in the names of the Trustees.

W. B. KEEN, *Chartered Accountant*,
3 Church Court, Old Jewry, E.C.
July 28, 1904.

Approved—
E. W. BRABROOK, } *Auditors.*
L. L. PRICE. }

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S. ...	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S....	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.........	—	—
1838, Aug. 10	Newcastle-on-Tyne...	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow...................	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S. ...	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S. ...	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S. ...	314	18
1848, Aug. 9	Swansea..................	The Marquis of Northampton, Pres.R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D. F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.......	235	9
1851, July 2.........	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S..................	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow..................	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S....	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S....	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S. ...	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S......	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne...	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham............	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham............	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S......	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S. ...	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.........	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S..........	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield................	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea..................	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.........	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S......	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S......	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne...	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham............	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S. ...	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S. ...	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover......................	Sir Michael Foster, K.C.B., Sec.R.S....	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11	Glasgow..................	Prof. A. W. Rücker, D.Sc., Sec.R.S. ...	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge..............	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	945 0 0	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting

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Report of the Council for the Year 1903–1904, *presented to the General Committee at Cambridge on Wednesday, August* 17, 1904.

The Trustees of the Association having consented to act as Trustees for the sum of 50*l.*, presented to the Association by the late Sir Frederick Bramwell, to provide for a report being prepared and presented at the Centenary Meeting of the Association 'dealing with the whole question of Prime Movers in 1931, and especially with the relation between steam engines and internal-combustion engines,' the money has been invested, in accordance with the suggestion made by Sir Frederick Bramwell, in $2\frac{1}{2}$ per cent. self-cumulative Consols.

The following resolutions having been referred to the Council by the General Committee for consideration, and action if desirable :—

> 1. The Committee of Section A, having received a communication from the International Meteorological Committee, is of opinion that the introduction of international uniformity in the units adopted for the records of Meteorological observations would be of great practical advantage to science, and that the Council be requested to take such steps as they may think fit toward giving effect to the resolution :—

the Council appointed a Committee, consisting of Lord Rayleigh, Dr. W. N. Shaw, Dr. R. H. Scott, Mr. C. V. Boys, Dr. R. T. Glazebrook, Professor Schuster, the President, and the General Officers, to report thereon.

The Council concur with the Committee in recommending that the process of arriving, if possible, at a general agreement as to the use of common units should be :—

(1) To prepare a statement of the considerations which would guide the choice of units ;

(2) To ascertain whether the meteorological authorities in this country would entertain proposals to select units on these considerations ;

(3) To ascertain whether (*a*) India, (*b*) the Colonial Organisations, would entertain similar proposals ;

(4) To approach the United States upon the matter ;

(5) To consult the meteorological organisations of foreign countries ; and finally

(6) To report the proceedings to the Association of Academies with a view to the adoption of a general system.

It would be desirable for the United States to be kept informed of the proceedings from the time that it is ascertained that the meteorological organisations of this country are willing to consider the matter, but it is not desirable to challenge a categorical reply until the attitude of the Colonies and dependencies is known.

A memorandum in accordance with recommendation (1) has been drawn up as a basis for discussion. The Meteorological Council, having already expressed a favourable opinion upon it from that point of view, the Council are taking steps to ascertain the views of the various authorities in the manner indicated in the foregoing paragraph, and it is hoped

that arrangements will be made for a discussion of the subject in Section A at Cambridge.

> 2. That the Council be asked to consider the desirability of permitting the publication of the whole of the Sectional Programmes in the daily Journal at as early a date as possible.
>
> 3. That it is desirable that further steps should be taken to make the Reports of Committees (as distinguished from papers) communicated to the Association more accessible to the general public by the provision of Indices to the published volumes and otherwise; and that the Council be asked to consider the conditions upon which reports of Committees and Proceedings of Sections might be published if required:

the Council appointed a Committee, consisting of Dr. Scott Keltie, Professor R. Meldola, Professor Perry, Professor W. W. Watts, the President, and the General Officers, to report on this matter.

The Council recommend—

(1) That the names of Members of the Sectional Committees be printed 'solid'—*i.e.* in continuous lines, and that additional names of Members elected during the meeting be added successively, at the end of the list printed in the Journal of the previous day.

(2) That the whole programme, so far as settled, of the proceedings of each Section be printed in the Journal issued on Thursday and each successive morning. The Recorders of Sections should be asked to furnish the programmes of their respective Sections several days before the commencement of the Meeting.

(3) That the publication of the list of papers read the previous day be discontinued.

(4) That the changes suggested in the publication of the reports be not adopted, the existing indices being sufficient for the present.

The Council desire to draw attention to the fact that two volumes of 'Indices'—namely, from 1831 to 1860, and from 1861 to 1890—have already been published and are on sale.

> 4. That the Sectional Committees be continued in existence until the new Sectional Committees are appointed, and be authorised to bring to the notice of the Council in the interval between the Annual Meetings of the Association any matter on which the action of the Council may be desired in the interests of the several Sections, and that a Committee may be summoned at any time by the President of the Section, or by the Council:

the Council, having considered the resolution, recommend that it be referred to the Committee of Recommendations.

> 5. That the Council be requested to consider the desirability of urging upon the Government, by a deputation to the First Lord of the Treasury or otherwise, the importance of increased national provision being made for University Education:

the Council considered the matter at a Special Meeting, when it was resolved:—

'That the President be requested to approach the various Universities and University Colleges, and to inquire (1) whether they would be willing to join in organising a deputation to the Prime Minister to ask for increased help to such institutions from Government funds; (2) whether they would each appoint representatives to a Joint Committee to organise such a deputation, it being understood that the deputation will consist

not merely of representatives of Universities, but of all those interested in the objects which it will be the aim of the deputation to secure.'

The communication made in pursuance of the foregoing resolution by the President to the various universities, university colleges, and large organisations interested in educational science, was replied to so favourably by them that steps were taken to organise a deputation to the First Lord of the Treasury.

A large and distinguished deputation, including representatives of all the universities, university colleges, and many county, municipal, and other educational authorities in the United Kingdom, was received by the Prime Minister, the Chancellor of the Exchequer also being present, on July 15, at the House of Commons. Prior to the deputation a memorandum had been drawn up by the President, and agreed to by the representatives of the principal universities, pointing out the necessity of a new departure on the part of the Government in relation to State Aid for Universities. This memorandum was forwarded to Mr. Balfour some days before the date of the deputation. The deputation was introduced by Sir Norman Lockyer. Mr. Pelham (representing Oxford) and Dr. Chase (Vice-Chancellor of Cambridge), on behalf of the older universities, and Mr. Chamberlain (Chancellor of the University of Birmingham), on behalf of the newer universities, addressed the Prime Minister, pointing out the need for much more liberal State aid being granted for purposes of higher education. Sir W. H. White and Sir W. Ramsay spoke of the importance of endowment of university teaching in relation to the application of science to the industries of the country. Sir R. Jebb mentioned the needs of the Humanity departments of universities. Sir Henry Roscoe discussed the importance of original research and its influence on our national well-being. Mr. A. Mosely, C.B., pointed out what was being done in other countries in practical university training for commercial and industrial life. Mr. Bell, M.P., spoke of the importance of university training being put within the reach, as regards expense, of the most promising minds in all classes of the community, so as to widen the area of selection for the higher activities of the nation.

Mr. Balfour, in reply to the deputation, said that he did not suppose there had ever been congregated in one chamber so many representatives of learning in this country, and hoped that they would forgive him if he did not wholly rise to the expectations formed of the answer he had to give on behalf of the Government. The words of his which had been quoted would, he hoped, absolve him from the necessity of again expressing sympathy with what he took to be the main object of the deputation. Though it has been said that we have fallen far behind at least two great countries in our national education, he absolutely denied that there is the smallest sign that in the production of the germinating ideas of science we have shown any inferiority. Germany has for many generations pursued the State-endowing process of applying science to industry, and in this we are far behind. The system of thought in Germany, the habits of the people, and the Government, in this respect place them at great advantage as compared to us, as far as endowment of universities can help a nation in the industrial struggle. But the mere endowment of universities will not, he thought, add greatly to the output of original work of the first quality. It will provide an education which will render

fit for industrial work persons who, without university education, would be very ill-equipped indeed. He concurred with all the speakers that there is a great financial need, both in the old and new universities, for help towards this object. But there is a still greater need—namely, that capitalists should recognise the necessity of giving employment to those whom the universities turn out. There is some evidence to show that shipbuilders and manufacturers prefer the future captains of industry to begin work early in life in the old way. He thought they were wrong, but they must be convinced that they are wrong, otherwise there will be no advantage in turning out qualified students if employers are content to use the man who acquires his training by actual day-to-day labour, but is not qualified in the higher scientific attainments which are more and more becoming necessary. Another thing we want is the creation of positions which will enable a man who has exceptional gifts of originality in science to devote his life to the subjects of his predilection, so as not to be driven to another kind of life in which he will not be able to render the full service of which he is capable to his country. In Germany such positions, which must in the main be attached to the universities, are more numerous than in this country. He could conceive no more admirable use of any funds which the universities can command than the increase of such positions. Having dealt with the more general aspects of the problem presented by the various speakers, he desired to leave it to the Chancellor of the Exchequer to speak upon the more practical question of what the Government can do and what it cannot do.

The Chancellor of the Exchequer said that he wished to express his interest in the work of universities, and recognised the larger part they were likely to play in our national development in the future. He considered it would be a misfortune if it were to be thought that it was the duty of the State to take upon itself the whole or main cost of the higher education of the country, or if the State were to come into such relations towards university education as it occupies towards elementary education. He must bid them consider what control the State would have to exercise, and what restrictions it might feel called upon to impose if it ever took on itself the duty of supplying to the universities such large grants as had been suggested. State aid must always be accompanied by State control, and it was, he thought, dangerous for the higher education of the country that it should have to conform itself, for the purpose of obtaining grants, to rules and regulations laid down by the Treasury. It would be not less disastrous in the interests of higher education if anything were done to relieve patriotic citizens of that sense of the importance of supporting higher education by voluntary endowment and subscription. The Government had not stinted their contributions to education as a whole. They had been spending large sums on primary and secondary education, which was a necessary equipment for any student who wished to make profitable use of the facilities the universities granted. The Government had shown their interest in universities this year by proposing to Parliament to double the grant recently given to university colleges, and had expressed a hope that in the coming year they might be able again to raise that sum so as, in round figures, to double it once more. We are not enjoying one of those periods of prosperity when the Treasury could afford to be generous without having to place fresh burdens on the taxpayer. Whatever the claims of university education to further assistance, they

must wait further development until the finances of the country are in an easier position. Beyond what he had stated it would be impossible to make in the next financial year further large contributions to university education. He thought that it would be of some assistance if universities would meanwhile consider to what extent they were willing to come under control if they received grants, to what extent the State was to have a voice in fixing the fees of students, and to what extent it was to direct or influence teaching, whether it was to allocate its assistance to promote special branches of study, or whether it was desired to make every university complete in itself.

Since the date of the deputation the President has been in correspondence with representatives of the universities, and he has reported that the Deputation Committee will probably hold another meeting in order to obtain further information from the universities to be laid before the Chancellor of the Exchequer.

The work of organising this deputation involved an amount of clerical work beyond the ordinary strength of the office, and special assistance had to be obtained for the purpose. Considerable expense has also been incurred in preparing and printing reports of the several meetings and conferences which have been held. A portion of the expenses falls into this year's accounts, and are included in the Treasurer's account.

In response to a Sectional resolution received too late for presentation to the General Committee last year requesting 'that the attention of the Council be called to the inconvenience which is caused to the Sections by gentlemen accepting the office of Vice-President neither appearing at the meeting nor sending a timely notice of their inability to do so,' the Council has resolved that gentlemen nominated as Vice-Presidents of Sections shall be informed that their attendance at the meeting for which they are nominated is expected.

The Council also recommend that each Sectional Committee shall have power to elect not more than three Vice-Presidents at any time during the meeting, in addition to those nominated by the Council and elected by the General Committee, and that the rules be altered accordingly.

Arrangements for the South African meeting in 1905 have received much attention during the year from a Committee of Council appointed for the purpose. The general arrangements for the meeting, which were preliminarily announced last year, have been confirmed, namely, that the first half of the meeting be held at Cape Town and the second half at Johannesburg, and that official visits of the Association be made to Natal and the Orange River Colony, in each of which Colonies one or more discourses will be delivered by prominent members of the Association. It has been found that the most convenient date for the meeting to open at Cape Town would be August 15, so that members starting for South Africa at the end of July could spend at least three weeks in the Colonies, and be back in England by the end of September.

An Additional Expenses Fund has been opened to supplement the subsidy to be given by the Colonial Governments of South Africa towards defraying the cost of the meeting, and subscriptions to the amount of 1,650*l*. have been received or promised. The Council hope that a considerably larger sum may be forthcoming during the ensuing year, so as to secure a thoroughly representative meeting in the Colonies of South Africa.

The Council have considered what alterations, if any, it may be desirable to make in the transaction of business at the South African meeting in consequence of the exceptional distance. They are of opinion that little alteration will be necessary in the custom other than that previously mentioned, and that no changes need be proposed in the written laws of the Association. There will, however, be difficulties in fixing the place of meeting for 1907, and the date of that in 1906, for delegates from the towns concerned could not be expected to attend. It may also be felt that members who are unable to leave the United Kingdom ought to have the opportunity of voting on these points, and on the election of the President and Officers for 1906. The Council therefore recommend that the General Committee hold only two meetings in South Africa, one at Cape Town and the other at Johannesburg, and an adjourned meeting at some convenient place in London on some day to be hereafter fixed towards the end of the month of October 1905.

An invitation to hold the Annual Meeting of the Association in 1906 will be presented from York. A letter has been received from the Lord Mayor and the Chancellor of the University of Melbourne expressing the strong desire of the Colony of Victoria that a meeting of the British Association may be held in Melbourne at a convenient date.

The Council nominate as additional Vice-Presidents of the Association for the Cambridge Meeting:—

His Grace the Duke of Devonshire, K.G., LL.D., F.R.S., Chancellor of the University of Cambridge.
Arthur Hall, Esq., M.A., D.L., High Sheriff of Cambridgeshire and Hunts.
The Right Rev. the Lord Bishop of Ely, D.D.
The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge.
The Right Hon. Lord Rayleigh, D.C.L., LL.D., F.R.S.
The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S.
The Right Rev. H. Montagu Butler, D.D., Master of Trinity.
Mrs. Henry Sidgwick, Principal of Newnham College.
J. H. Chesshyre Dalton, Esq., M.D., Mayor of Cambridge.
Robert Stephenson, Esq., Chairman of the Cambridgeshire County Council.
Joseph Martin, Esq., Chairman of the Isle of Ely County Council.

The Council nominate as Sectional Officers the various gentlemen whose names appear on the programme of the Cambridge Meeting.

The Council nominate Principal E. H. Griffiths, F.R.S., Chairman, Dr. Tempest Anderson, Vice-Chairman, and Mr. F. W. Rudler, Secretary of the Conference of Delegates of Corresponding Societies to be held during the Cambridge Meeting.

A Report has been received from the Corresponding Societies Committee, together with the list of the Corresponding Societies and the titles of the more important papers, especially of those referring to Local Scientific Investigations, published by the Societies during the year ending May 31, 1903.

The Council nominate for election as the Corresponding Societies Committee for the ensuing year the following members:—Mr. W. Whitaker (Chairman), Mr. F. W. Rudler (Secretary), Rev. J. O. Bevan, Dr. Horace T. Brown, Dr. Vaughan Cornish, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Professor W. W. Watts, and the General Officers of the Association.

The Council have received reports from the General Treasurer during

the past year, and his accounts from July 1, 1903, to June 30, 1904, have been audited and are presented to the General Committee.

The Council having been informed by Dr. G. Carey Foster that he does not intend to offer himself for re-election as General Treasurer at the Cambridge meeting, desire to put on record an expression of their high appreciation of the value of the services rendered to the Association by him, and their great regret that he feels it needful to resign.

The Council recommend that Professor John Perry, F.R.S., be appointed General Treasurer in succession to Dr. G. Carey Foster. The confirmation of this recommendation will cause a vacancy on the Council.

In accordance with the regulations the retiring members of the Council will be as follows :—By seniority, Dr. J. Scott Keltie, Mr. L. L. Price, and Professor W. A. Tilden ; by least attendance, Professor G. B. Howes and Sir J. Wolfe-Barry (resigned in November last).

The Council recommend the re-election of the other ordinary members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Abney, Sir W., K.C.B., F.R.S.
Armstrong, Professor H. E., F.R.S.
Bonar, J., Esq., LL.D.
Bourne, G. C., Esq., D.Sc.
Bower, Professor F. O., F.R.S.
Brabrook, E. W., Esq., C.B.
*Brown, Dr. Horace T., F.R.S.
Callendar, Professor H. L., F.R.S.
Cunningham, Professor D. J., F.R.S.
Darwin, Major L., Sec. R.G.S.
Gotch, Professor F., F.R.S.
Haddon, Dr. A. C., F.R.S.
Hawksley, C., Esq., M.Inst.C.E.
*Higgs, Henry, Esq., LL.B.
*Langley, Professor J. N., F.R.S.
Macalister, Professor A., F.R.S.
McKendrick, Professor J.G., F.R.S.
*Mackinder, H. J., Esq., M.A.
Noble, Sir A., Bart., K.C.B., F.R.S.
Perkin, Professor W. H., F.R.S.
Seward, A. C., Esq., F.R.S.
*Shaw, Dr. W. N., F.R.S.
*Shipley, A. E., Esq., F.R.S.
Watts, Professor W. W., F.R.S.
Woodward, Dr. A. Smith, F.R.S.

The following claims for admission to the General Committee have been allowed by the Council :—

S. Monckton Copeman, M.D., F.R.S.
F. W. Edridge-Green, M.D., F.R.C.S.
William J. S. Lockyer, Ph.D.
John Morrow, M.Sc.
A. B. Rendle, M.A., D.Sc.
Alfred R. Sennett.

Committees appointed by the General Committee at the Cambridge Meeting in August 1904.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants
	Section A.—MATHEMATICS AND PHYSICS.	£ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Lord Rayleigh. *Secretary.*—Dr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and G. Carey Foster, Sir Oliver Lodge, Dr. A. Muirhead, Sir W. H. Preece, Professor A. Schuster, Dr. J. A. Fleming, Professor J. J. Thomson, Dr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Principal E. H. Griffiths, Sir A. W. Rücker, Professor H. L. Callendar, and Mr. G. Matthey.	40 0 0
Seismological Observations.	*Chairman.*—Professor J. W. Judd. *Secretary.*—Mr. J. Milne. Lord Kelvin, Professor T. G. Bonney, Mr. C. V. Boys, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Mr. M. H. Gray, Dr. R. T. Glazebrook, Professor C. G. Knott, Professor R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, Mr. Nelson Richardson, and Professor H. H. Turner.	40 0 0
To co-operate with the Royal Meteorological Society in initiating an Investigation of the Upper Atmosphere by means of Kites.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. W. H. Dines. Mr. D. Archibald, Mr. C. Vernon Boys, Dr. A. Buchan, Dr. R. T. Glazebrook, Dr. H. R. Mill, Dr. A. Schuster, and Dr. W. Watson.	40 0 0
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Dr. R. T. Glazebrook. Professor W. G. Adams, Captain Creak, Mr. W. L. Fox, Professor A. Schuster, and Sir A. W. Rücker.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
	SECTION B.—CHEMISTRY.	
		£ s. d.
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir Norman Lockyer, Professors Sir J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, Sir W. de W. Abney, and Dr. W. E. Adeney.	5 0 0
The Study of Hydro-aromatic Substances.	*Chairman.*—Professor E. Divers. *Secretary.*—Dr. A. W. Crossley. Professor W. H. Perkin, Dr. M. O. Forster, and Dr. Le Sueur.	25 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. J. J. Dobbie, Dr. A. Lapworth, and Dr. M. O. Forster.	20 0 0
The Transformation of Aromatic Nitramines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann, Dr. A. Lapworth, and Dr. J. T. Hewitt.	
	SECTION C.—GEOLOGY.	
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Dr. J. E. Marr. *Secretary.*—Mr. P. F. Kendall. Professor T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Dr. J. Horne, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, Mr. W. T. Tucker, and Mr. F. W. Harmer.	10 0 0 and unexpended balance.
The Movements of Underground Waters of North-west Yorkshire.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Mr. A. R. Dwerryhouse. Professor A. Smithells, Rev. E. Jones, Mr. Walter Morrison, Mr. G. Bray, Rev. W. Lower Carter, Mr. T. Fairley, Professor P. F. Kendall, and Dr. J. E. Marr.	Balance in hand.

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Dr. J. E. Marr. *Secretary.*—Dr. Wheelton Hind. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Professor E. J. Garwood, Dr. G. J. Hinde, Professor P. F. Kendall, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. B. N. Peach, Mr. J. T. Stobbs, Mr. A. Strahan, Mr. D. T. Gwynne Vaughan, and Dr. H. Woodward.	£ s. d. Balance in hand.
To report upon the Fauna and Flora of the Trias of the British Isles.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. J. Lomas. Professors W. W. Watts and P. F. Kendall, and Messrs H. C. Beasley, E. T. Newton, A. C. Seward, and W. A. E. Ussher.	10 0 0
To investigate the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.	*Chairman.*—Mr. G. W. Lamplugh. *Secretary.*—Mr. J. W. Stather. Dr. Tempest Anderson, Professor J. W. Carr, Rev. W. Lower Carter, Messrs. A. R. Dwerryhouse, F. W. Harmer, and J. H. Howarth, Rev. W. Johnson, and Messrs. P. F. Kendall, E. T. Newton, H. M. Platnauer, Clement Reid, and T. Sheppard.	Balance in hand.
	SECTION D.—ZOOLOGY.	
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Rev. T. R. R. Stebbing. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor G. B. Howes, Mr. A. Sedgwick, Professor W. C. McIntosh, and Mr. G. P. Bidder.	100 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Dr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. W. E. Hoyle, and the Hon. Walter Rothschild.	75 0 0
To enable Mr. J. W. Jenkinson to continue his Researches on the Influence of Salt and other Solutions on the Development of the Frog.	*Chairman.*—Professor Weldon. *Secretary.*—Mr. J. W. Jenkinson. Professor S. J. Hickson.	10 0 0 and unexpended balance.

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To enable Dr. F. W. Gamble and Mr. F. W. Keeble to conduct Researches on the relation between Respiratory Phenomena and Colour Changes in the Higher Crustacea.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Dr. F. W. Gamble. Dr. Hoyle and Mr. F. W. Keeble.	15 0 0 and unexpended balance.

Section E.—GEOGRAPHY.

To carry on an Expedition to investigate the Indian Ocean between India and South Africa in view of a possible land connection, to examine the deep submerged banks, the Nazareth and Saza de Malha, and also the distribution of Marine Animals.	*Chairman.*—Sir John Murray. *Secretary.*—Mr. J. Stanley Gardiner. Dr. W. T. Blanford, Captain E. W. Creak, Professors W. A. Herdman, S. J. Hickson, and J. W. Judd, Mr. J. J. Lister, Dr. H. R. Mill, and Admiral Sir W. J. L. Wharton.	150 0 0

Section F.—ECONOMIC SCIENCE AND STATISTICS.

The Accuracy and Comparability of British and Foreign Statistics of International Trade.	*Chairman.*—Dr. E. Cannan. *Secretary.*—Dr. W. G. S. Adams. Mr. A. L. Bowley, Professor S. J. Chapman, and Sir R. Giffen.	20 0 0

Section H.—ANTHROPOLOGY.

To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Sir John Evans. *Secretary.*—Mr. J. L. Myres. Mr. R. C. Bosanquet, Mr. A. J. Evans, Mr. D. G. Hogarth, Professor A. Macalister, and Professor W. Ridgeway.	75 0 0 and unexpended balance.
To investigate the Lake Village at Glastonbury, and to report on the best method of publication of the result.	*Chairman.*—Dr. R. Munro. *Secretary.*—Professor W. Boyd Dawkins. Sir John Evans and Messrs. Arthur J. Evans, C. H. Read, H. Balfour, and A. Bulleid.	Balance in hand.
To conduct Anthropometric Investigations among the Native Troops of the Egyptian Army.	*Chairman.*—Professor A. Macalister. *Secretary.*—Dr. C. S. Myers. Sir John Evans and Professor D. J. Cunningham.	10 0 0
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Dr. A. J. Evans. *Secretary.*—Mr. J. L. Myres. Professor Boyd Dawkins, Mr. E. W. Brabrook, Mr. T. Ashby, and Professor W. Ridgeway.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To organise Anthropometric Investigation in the British Isles.	*Chairman.*—Professor D. J. Cunningham. *Secretary.*—Mr. J. Gray. Dr. A. C. Haddon, Dr. C. S. Myers, Mr. J. L. Myres, Professor A. F. Dixon, Mr. E. N. Fallaize, Mr. Randall MacIver, Professor J. Symington, Dr. Waterston, Mr. E. W. Brabrook, Dr. T. H. Bryce, Mr. W. H. L. Duckworth, Mr. G. L. Gomme, Dr. F. C. Shrubsall, Professor G. D. Thane, and Mr. J. F. Tocher.	10 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. Balfour. Sir John Evans, Dr. J. G. Garson, Mr. A. J. Evans, Dr. R. Munro, Professor Boyd Dawkins, and Mr. A. L. Lewis.	40 0 0
The present state of Anthropological Teaching in the United Kingdom and elsewhere.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. J. L. Myres. Professor A Macalister, Dr. A. C. Haddon, Mr. C. H. Read, Mr. H. Balfour, Mr. F. W. Rudler, Dr R. Munro, Professor Flinders Petrie, Mr. H. Ling Roth, and Professor D. J. Cunningham.	Balance in hand.
	Section I.—PHYSIOLOGY.	
The State of Solution of Proteids.	*Chairman.*—Professor W. D. Halliburton. *Secretary.*—Professor E. Waymouth Reid. Professor E. A. Schäfer.	20 0 0
To enable Professor Starling, Professor Brodie, Dr. Hopkins, Mr. Fletcher, Mr. Barcroft, and others to determine the 'Metabolic Balance Sheet' of the Individual Tissues.	*Chairman.*—Professor Gotch. *Secretary.*—Mr. J. Barcroft. Sir Michael Foster and Professor Starling.	30 0 0 and unexpended balance.
The Ductless Glands.	*Chairman.*—Professor Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, Mr. J. Barcroft.	40 0 0
	Section K.—BOTANY.	
To carry out the scheme for the Registration of Negatives of Botanical Photographs.	*Chairman.*—Professor L. C. Miall. *Secretary.*—Professor F. E. Weiss. Mr. Francis Darwin, Dr. W. G. Smith, and Mr. A. G. Tansley.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Professor H. Marshall Ward. *Secretary.*—Mr. A. C. Seward. Professor J. B. Farmer and Dr. D. Sharp.	35 0 0
The Structure of Fossil Plants.	*Chairman.*—Dr. D. H. Scott. *Secretary.*—Professor F.W. Oliver Messrs. A. C. Seward and E. Newell Arber.	50 0 0

Section L.—EDUCATIONAL SCIENCE.

To report upon the Course of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.	*Chairman.*—Sir Philip Magnus. *Secretary.*—Mr. W. M. Heller. Sir W. de W. Abney, Mr. R. H. Adie, Professor H. E. Armstrong, Miss A. J. Cooper, Miss L. J. Clarke, Mr. George Fletcher, Professor R. A. Gregory, Principal Griffiths, Mr. A. D. Hall, Mr. A. J. Herbertson, Dr. C. W. Kimmins, Professor J. Perry, Mrs. W. N. Shaw, Professor A. Smithells, Dr. Lloyd Snape, Principal Reichel, Mr. H. Richardson, Mr. Harold Wager, Miss Edna Walter, and Professor W. W. Watts.	20 0 0

CORRESPONDING SOCIETIES.

Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. F. W. Rudler. Rev. J. O. Bevan, Dr. H. T. Brown, Dr. Vaughan Cornish, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Professor R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Prof. W. W. Watts, and the General Officers of the Association.	20 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Sir John Murray, Dr. A. Buchan, Professor R. Copeland, and Mr. Omond.
The Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.	*Chairman* and *Secretary.*—Professor H. L. Callendar. Lord Kelvin, Sir Archibald Geikie, Professor Edward Hull, Professor A. S. Herschel, Professor G. A. Lebour, Dr. C. H. Lees, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. Edward Wethered, Mr. A. Strahan, Professor Michie Smith, and Mr. B. H. Brough.
The Consideration of the Teaching of Elementary Mechanics, and the Improvement which might be effected in such Teaching.	*Chairman.*—Professor Horace Lamb. *Secretary.*—Professor J. Perry. Mr. C. Vernon Boys, Professors Chrystal, Ewing, G. A. Gibson, and Greenhill, Principal Griffiths, Professor Henrici, Dr. E. W. Hobson, Mr. C. S. Jackson, Sir Oliver Lodge, Professors Love, Minchin, and Schuster, and Mr. A. W. Siddons.
That Miss Hardcastle be requested to continue her Report on the present state of the Theory of Point-groups.	
SECTION B.—CHEMISTRY.	
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Dr. W. P. Wynne and Professor W. J. Pope.
SECTION C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, Professors E. J. Garwood and S. H. Reynolds, and Messrs. A. S. Reid, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, J. G. Goodchild, H. Coates, C. V. Crook, G. Bingley, B. Welch, and W. J. Harrison.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To record and determine the Exact Significance of Local Terms applied in the British Isles to Topographical and Geological Objects.	*Chairman.*—Mr. Douglas W. Freshfield. *Secretary.*—Mr. W. G. Fearnsides. Lord Avebury, Mr. C. T. Clough, Professor E. J. Garwood, Mr. E. Heawood, Dr. A. J. Herbertson, Col. D. A. Johnston, Mr. O. T. Jones, Dr. J. S. Keltie, Mr. G. W. Lamplugh, Mr. H. J. Mackinder, Dr. E. J. Marr, Dr. H. R. Mill, Mr. H. Yule Oldham, Dr. B. Peach, Professor W. W. Watts, and Mr. H. B. Woodward.

Section D.—ZOOLOGY.

To continue the Investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.
To conduct an Investigation into the Madreporaria of the Bermuda Islands.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Dr. W. E. Hoyle. Dr. F. F. Blackman, Mr. J. S. Gardiner, Professor W. A. Herdman, Mr. A. C. Seward, Professor C. S. Sherrington, and Mr. A. G. Tansley.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors T. W. Bridge, J. Cossar Ewart, M. Hartog, W. A. Herdman, and J. Graham Kerr, Mr. O. H. Latter, Professor Minchin, Dr. P. C. Mitchell, Professor C. Lloyd Morgan, Professor E. B. Poulton, Mr. A. Sedgwick, Mr. A. E. Shipley, and Rev. T. R. R. Stebbing.
To inquire into the probability of *Ankylostoma* becoming a permanent inhabitant of our coal mines in the event of its introduction, with power to issue an interim report.	*Chairman.*—Mr. A. E. Shipley. *Secretary.*—Mr. G. P. Bidder. Mr. G. H. F. Nuttall.
To enable Miss Igerna Sollas, of Newnham College, Cambridge, to study certain points in the development of Ophiusoids, and to enable other competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman and Secretary.*—Mr. W. Garstang. Professor E. Ray Lankester, Mr. A. Sedgwick, Professor Sydney H. Vines, and Professor W. F. R. Weldon.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To enable Dr. H. W. Marett Tims to conduct experiments with regard to the effect of the Sera and Antisera on the Development of the Sexual Cells.	*Chairman.*—Mr. G. H. F. Nuttall. *Secretary.*—Dr. H. W. Marett Tims. Mr. J. Stanley Gardiner.

SECTION E.—GEOGRAPHY.

Terrestrial Surface Waves.	*Chairman.*—Dr. J. Scott Keltie. *Secretary.*—Dr. Vaughan Cornish. Lieut.-Col. F. Bailey and Messrs. John Milne, W. H. Wheeler, and W. Whitaker.
The continued Investigation of the Oscillations of the Level of the Land in the Mediterranean Basin.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Mr. R. T. Günther. Drs. T. G. Bonney, F. H. Guillemard, J. S. Keltie, and H. R. Mill.

SECTION G.—ENGINEERING.

To investigate the Resistance of Road Vehicles to Traction.	*Chairman.*—Sir J. I. Thornycroft. *Secretary.*—Mr. A. Mallock. Mr. T. Aitken, Mr. T. C. Aveling, Professor T. Hudson Beare, Mr. W. W. Beaumont, Mr. J. Brown, Colonel R. E. Crompton, Mr. B. J. Diplock, Professor J. Perry, Sir D. Salomons, Mr. A. R. Sennett, Mr. E. Shrapnell Smith, and Professor W. C. Unwin.
To consider the Incidence of the Patent and Design Laws upon the National Development of the Practical Applications of Science.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Sir H. Trueman Wood. Mr. C. D. Abel, Mr. Dugald Clerk, Dr. R. T. Glazebrook, Mr. R. A. Hadfield, Hon. C. A. Parsons, Mr. A. Siemens, and Major-General Webber.

SECTION H.—ANTHROPOLOGY.

he Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. H. S. Kingsford. Dr. J. G. Garson, Mr. H. Ling Roth, Mr. H. Balfour, Dr. A. C. Haddon, Mr. E. S. Hartland, Mr. E. Heawood, Professor Flinders Petrie, Mr. E. N. Fallaize, and Mr. J. L. Myres.
To report on the present state of knowledge of the Ethnography, Folklore, and Languages of the Peoples of the Pacific, with a view to further research.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Dr. A. C. Haddon. Mr. H. Balfour and Mr. J. Stanley Gardiner.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To consider what steps may be taken to organise Anthropological Teaching and Research in the British Empire.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. J. L. Myres. Mr. H. Balfour, Professor D. J. Cunningham, Mr. G. L. Gomme, Dr. A. C. Haddon, Professor A. Macalister, Dr. C. S. Myers, Professor Flinders Petrie, Mr. C. H. Read, and Mr. F. W. Rudler.
Excavations on Prehistoric Sites in South Africa.	*Chairman.*—Mr. H. Balfour. *Secretary.*—Mr. J. L. Myres. Sir David Gill, Dr. A. C. Haddon, and Professor H. A. Miers.

Section I.—PHYSIOLOGY.

The Physiological Effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor W. H. Thompson. Professors R. Boyce and C. S. Sherrington.

Section L.—EDUCATIONAL SCIENCE.

The conditions of Health essential to the carrying on of the work of instruction in schools.	*Chairman.*—Professor Sherrington. *Secretary.*—Mr. E. White Wallis. Mr. E. W. Brabrook, Dr. C. W. Kimmins, Professor L. C. Miall, and Miss Maitland.
To consider and report upon the influence exercised by Universities and Examining Bodies on secondary school curricula, and also of the schools on university requirements.	*Chairman.*—Dr. H. E. Armstrong. *Secretary.*—Mr. R. A. Gregory. The Bishop of Hereford, Sir Michael Foster, Sir P. Magnus, Sir A. W. Rücker, Sir O. J. Lodge, Mr. H. W. Eve, Mr. W. A. Shenstone, Mr. W. D. Eggar, Professor Marshall Ward, Mr. F. H. Neville, Mrs. W. N. Shaw, and Dr. C. W. Kimmins.
The Training of Teachers.	*Chairman.*—The Bishop of Hereford. *Secretary.*—Mr. J. L. Holland. Professor H. E. Armstrong, Mr. Oscar Browning, Miss A. J. Cooper, Mr. Ernest Gray, and Dr. H. B. Gray.

Communications ordered to be printed in extenso.

The Stereochemistry of Nitrogen. By Dr. H. O. Jones.
Dynamic Isomerism. By Dr. T. M. Lowry.
On the Wells of Cambridgeshire. By W. Whitaker, F.R.S.

Resolutions referred to the Council for consideration, and action if desirable.

From Section A.

(i.) The Committee think it desirable that information as to reports and papers sent to the General Secretary for communication to any Section should be forwarded to the Recorder of the Section concerned as soon as possible after it is received at the office.

(ii.) The Committee of Section A desire to draw the attention of the Committee of Recommendations to the concluding portion of Sir John Eliot's Introductory Address to the Sub-Section for Astronomy and Cosmical Physics, and to express the opinion that the organisation of a Central Meteorological Department for the British Empire would be of the highest benefit to the progress of Meteorological Science and its application to the economic problems of the various Colonies and Dependencies. The object of each department would be to collect and prepare digests of the Meteorological observations taken in different parts of the Empire, to provide a scientific staff for dealing with the more general Meteorological problems, including their relations to Solar Physics and Terrestrial Magnetism, which involve the co-ordination of data from wide areas, and to promote experimental investigations of the scientific questions which arise in connection with such discoveries. The Committee desire also to express the opinion that the reorganisation of the Meteorological Office, which is at present before the Government, affords an exceptionally favourable opportunity for the establishment of such a central Meteorological Department for the Empire.

From Section F.

(i.) That it is desirable that the Reports of Committees, especially where they extend over two or more years, should be offered for public circulation in a separate form from the annual volume of Reports, at a small price, say 6*d*. per copy.

(ii.) That as there has been a great demand for copies of the Reports of the Women's Labour Committee of this Section, and it has been impossible to satisfy it, these Reports be printed and sold separately at the smallest charge possible.

From the Conference of Delegates.

(i.) That a Committee be appointed, consisting of Members of the Council of the Association, together with representatives of the Corresponding Societies, to consider the present relation between the British Association and local Scientific Societies.

That the Committee be empowered to make suggestions to the Council with a view to the greater utilisation of the connection between the Association and the affiliated Societies, and the extension of affiliation to other Societies who are at present excluded under Regulation 1.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Cambridge Meeting, August 1904. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Rayleigh, Lord—Electrical Standards	40	0	0
*Judd, Professor J. W.—Seismological Observations	40	0	0
*Shaw, Dr. W. N.—Investigations of the Upper Atmosphere by means of Kites	40	0	0
*Preece, Sir W. H.—Magnetic Observations at Falmouth ...	50	0	0

Chemistry.

*Roscoe, Sir H. E.—Wave-length Tables of Spectra	5	0	0
*Divers, Professor E.—Study of Hydro-Aromatic Substances	25	0	0
Armstrong, Professor H. E.—Dynamic Isomerism	20	0	0
Kipping, Professor F. S.—Aromatic Nitramines	25	0	0

Geology.

*Marr, Dr. J. E.—Erratic Blocks (and unexpended balance)	10	0	0
*Watts, Professor W. W.—Movements of Underground Waters (balance in hand)		—	
*Marr, Dr. J. E.—Life-zones in British Carboniferous Rocks (balance in hand)		—	
*Herdman, Professor W. A.—Fauna and Flora of British Trias	10	0	0
*Lamplugh, G. W.—Fossiliferous Drift Deposits (balance in hand)		—	

Zoology.

*Hickson, Professor S. J.—Table at Zoological Station at Naples	100	0	0
*Woodward, Dr. H.—Index Animalium	75	0	0
*Weldon, Professor—Development of Frog (and unexpended balance)	10	0	0
*Hickson, Professor S. J.—Higher Crustacea (and unexpended balance)	15	0	0

Geography.

Murray, Sir J.—Investigations in the Indian Ocean	150	0	0

Economic Science and Statistics.

*Cannan, Dr. E.—British and Foreign Statistics of International Trade	20	0	0
Carried forward	£635	0	0

* Reappointed.

	£	s.	d.
Brought forward	635	0	0

Anthropology.

*Evans, Sir J.—Excavations in Crete (and unexpended balance)	75	0	0
*Munro, Dr. R.—Lake Village at Glastonbury (balance in hand)	—		
*Macalister, Professor A.—Anthropometry of Native Egyptian Troops	10	0	0
*Evans, A. J.—Excavations on Roman Sites in Britain	10	0	0
*Cunningham, Professor D. J.—Anthropometric Investigation in Great Britain and Ireland	10	0	0
*Read, C. H.—Age of Stone Circles	40	0	0
*Tylor, Professor E. B.—Anthropological Teaching (balance in hand)	—		

Physiology.

*Halliburton, Professor W. D.—The State of Solution of Proteids	20	0	0
*Gotch, Professor—Metabolism of Individual Tissues (and unexpended balance)	30	0	0
Schäfer, Professor—The Ductless Glands	40	0	0

Botany.

*Miall, Professor—Botanical Photographs	5	0	0
*Ward, Professor H. Marshall—The Physiology of Heredity	35	0	0
Scott, Dr. D. H.—The Structure of Fossil Plants	50	0	0

Educational Science.

*Magnus, Sir P.—Studies Suitable for Elementary Schools	20	0	0

Corresponding Societies Committee.

*Whitaker, W.—Preparing Report, &c.	20	0	0
	£1,000	0	0

* Reappointed.

The Annual Meeting in 1905.

The Annual Meeting of the Association in 1905 will be held in South Africa, commencing, August 15, at Cape Town.

The Annual Meeting in 1906.

The Annual Meeting of the Association in 1906 will be held at York.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells ...	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology.........1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu......	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals......	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh..................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall .	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York..	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay..............................	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers................	11	7	6
Anemometers' Repairs...	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 .... £ 75 0 0; 1855 .... £500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seed	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee...............	64	13	4
Balloon Committee	50	0	0
Metrical Committee...........	50	0	0
British Rainfall.................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards...........	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water.......................	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania...........	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine.......................	50	0	0
Lunar Committee	120	0	0
Metrical Committee............	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations.........	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards...........	100	0	0
Ethyl and Methyl Series......	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture...	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee...........	50	0	0
Zoological Record..............	100	0	0
Kent's Hole Explorations .	150	0	0
Steamship Performances . ..	100	0	0
British Rainfall	50	0	0
Luminous Meteors..............	50	0	0
Organic Acids	60	0	0
Fossil Crustacea.................	25	0	0
Methyl Series....................	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall..................	50	0	0
Thermal Conductivity of Iron, &c.................................	30	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron.......................	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series....................	30	0	0
Organic Remains in Limestone Rocks.....................	10	0	0
Earthquakes in Scotland......	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee ...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station ...	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee ...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory........	150	0	0
Electrical Standards...........	2	6	4
Magnetic Observations.........	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives............................	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington...	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford...	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society ...	50	0	0
Pliocene Fauna of St. Erth...	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station ...	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei ...	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
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Effect of Occupations on Physical Development...........	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands..........................	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards............	75	0	0
Electrolysis.......................	20	0	0
Surface Water Temperature...	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record..............	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations ...	100	0	0
Flora of China	25	0	0
Naples Zoological Station ...	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands..........................	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath.. ...	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards...........	12	17	0
Electrolysis	5	0	0
Electro-optics....................	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters.........................	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton ...	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel...	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire ...	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis ...	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands...	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory...	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis ...	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia......	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards...........	25	0	0
Photographs of Meteorological Phenomena......................	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables...........	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills............................	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave.....	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart...........	10	0	0
Exploration in Abyssinia ...	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics.......................	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury..............................	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children..............	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards...........	25	0	0
Photographs of Meteorological Phenomena.....................	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives...........................	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills..................................	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea..............	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut ...	50	0	0
Calibration and Comparison of Measuring Instruments ...	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph...............	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
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Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
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Palæolithic Deposits at Hoxne	25	0	0
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Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
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Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours	8	0	0
Erratic Blocks	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest	10	0	0
Life-zones in British Carboniferous Rocks..................	15	0	0
Pleistocene Fauna and Flora in Canada	20	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	14	0	0
Index Generum et Specierum Animalium	100	0	0
Healthy and Unhealthy Oysters	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries	15	0	0
Small Screw Gauge	20	0	0
North-Western Tribes of Canada........	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee	25	0	0
	£1,212	0	0

	£	s.	d.
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Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	100	0	0
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Plankton and Physical Conditions of the English Channel during 1899	100	0	0
Exploration of Sokotra	35	0	0
Lake Village at Glastonbury	50	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	35	0	0
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1901.

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General Meetings.

On Wednesday, August 17, at 8.30 P.M., in the Corn Exchange, Sir Norman Lockyer, K.C.B., LL.D., F.R.S., resigned the office of President to the Right Hon. Arthur James Balfour, D.C.L., LL.D., M.P., F.R.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, August 18, at 5 P.M., in the Theatre, Mr. J. W. Clark delivered a Lecture on 'The Origin and Growth of the University of Cambridge;' and at 9 P.M., a Soirée took place at Trinity College.

On Friday, August 19, at 8.30 P.M., in the Theatre, Professor G. H. Darwin, F.R.S., delivered a Discourse on 'Ripple-Marks and Sand-Dunes.'

On Monday, August 22, at 8.30 P.M., in the Theatre, Professor H. F. Osborn delivered a Discourse on 'Palæontological Discoveries in the Rocky Mountains.'

On Wednesday, August 24, at 2.30 P.M., in the Senate House, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to South Africa. [The Meeting is appointed to commence at Cape Town, on Tuesday, August 15, 1905.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

THE RIGHT HON. A. J. BALFOUR, D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh.

PRESIDENT.

Reflections suggested by the New Theory of Matter.

THE meetings of the British Association have for the most part been held in crowded centres of population, where our surroundings never permit us to forget, were such forgetfulness in any case possible, how close is the tie that binds modern science to modern industry, the abstract researches of the student to the labours of the inventor and the mechanic. This, no doubt, is as it should be. The interdependence of theory and practice cannot be ignored without inflicting injury on both ; and he is but a poor friend to either who undervalues their mutual co-operation.

Yet, after all, since this great Society exists for the advancement of science, it is well that now and again we should choose our place of gathering in some spot where science rather than its applications, knowledge, not utility, are the ends to which research is primarily directed.

If this be so, surely no happier selection could have been made than the quiet courts of this ancient University. For here, if anywhere, we tread the classic ground of physical discovery. Here, if anywhere, those who hold that physics is the true *Scientia Scientiarum*, the root of all the sciences which deal with inanimate nature, should feel themselves at home. For, unless I am led astray by too partial an affection for my own University, there is nowhere to be found, in any corner of the world, a spot with which have been connected, either by their training in youth, or by the labours of their maturer years, so many men eminent as the originators of new and fruitful physical conceptions. I say nothing of Bacon, the eloquent prophet of a new era ; nor of Darwin, the Copernicus of Biology ; for my subject to-day is not the contributions of Cambridge to the general growth of scientific knowledge. I am concerned rather with the illustrious line of physicists who have learned or taught within a few hundred yards of this building—a line stretching from Newton in the seventeenth century, through Cavendish in the eighteenth, through Young, Stokes, Maxwell, in the nineteenth, through Kelvin, who embodies an epoch in himself, down to Rayleigh, Larmor, J. J. Thomson, and the

scientific school centred in the Cavendish laboratory, whose physical speculations bid fair to render the closing years of the old century and the opening years of the new as notable as the greatest which have preceded them.

Now what is the task which these men, and their illustrious fellow-labourers out of all lands, have set themselves to accomplish? To what end led these 'new and fruitful physical conceptions' to which I have just referred? It is often described as the discovery of the 'laws connecting phenomena.' But this is certainly a misleading, and in my opinion a very inadequate, account of the subject. To begin with, it is not only inconvenient, but confusing, to describe as 'phenomena' things which do not appear, which never have appeared, and which never can appear, to beings so poorly provided as ourselves with the apparatus of sense-perception. But apart from this, which is a linguistic error too deeply rooted to be easily exterminated, is it not most inaccurate in substance to say that a knowledge of Nature's laws is all we seek when investigating Nature? The physicist looks for something more than what, by any stretch of language, can be described as 'co-existences' and 'sequences' between so called 'phenomena.' He seeks for something deeper than the laws connecting possible objects of experience. His object is physical reality: a reality which may or may not be capable of direct perception; a reality which is in any case independent of it; a reality which constitutes the permanent mechanism of that physical universe with which our immediate empirical connection is so slight and so deceptive. That such a reality exists, though philosophers have doubted, is the unalterable faith of science; and were that faith *per impossibile* to perish under the assaults of critical speculation, science, as men of science usually conceive it, would perish likewise.

If this be so, if one of the tasks of science, and more particularly of physics, is to frame a conception of the physical universe in its inner reality, then any attempt to compare the different modes in which, at different epochs of scientific development, this intellectual picture has been drawn, cannot fail to suggest questions of the deepest interest. True, I am precluded from dealing with such of these questions as are purely philosophical by the character of this occasion; and with such of them as are purely scientific by my own incompetence. But some there may be sufficiently near the dividing line to induce the specialists who rule by right on either side of it, to view with forgiving eyes any trespasses into their legitimate domain which I may be tempted, during the next few minutes, to commit.

Let me then endeavour to compare the outlines of two such pictures, of which the first may be taken to represent the views prevalent towards the end of the eighteenth century; a little more than a hundred years from the publication of Newton's 'Principia,' and, roughly speaking, about midway between that epoch-making date and the present moment. I suppose that if at that period the average man of science had been asked

to sketch his general conception of the physical universe, he would probably have said that it essentially consisted of various sorts of ponderable matter, scattered in different combinations through space, exhibiting most varied aspects under the influence of chemical affinity and temperature, but through every metamorphosis obedient to the laws of motion, always retaining its mass unchanged, and exercising at all distances a force of attraction on other material masses, according to a simple law. To this ponderable matter he would (in spite of Rumford) have probably added the so-called 'imponderable' heat, then often ranked among the elements; together with the two 'electrical fluids,' and the corpuscular emanations supposed to constitute light.

In the universe as thus conceived the most important form of action between its constituents was action at a distance; the principle of the conservation of energy was, in any general form, undreamed of; electricity and magnetism, though already the subjects of important investigation, played no great part in the Whole of things; nor was a diffused ether required to complete the machinery of the universe.

Within a few months, however, of the date assigned for these deliverances of our hypothetical physicist, came an addition to this general conception of the world, destined profoundly to modify it. About a hundred years ago Young opened, or re-opened, the great controversy which finally established the undulatory theory of light, and with it a belief in an interstellar medium by which undulations could be conveyed. But this discovery involved much more than the substitution of a theory of light which was consistent with the facts for one which was not; since here was the first authentic introduction [1] into the scientific world-picture of a new and prodigious constituent—a constituent which has altered, and is still altering, the whole balance (so to speak) of the composition. Unending space, thinly strewn with suns and satellites, made or in the making, supplied sufficient material for the mechanism of the heavens as conceived by Laplace. Unending space filled with a continuous medium was a very different affair, and gave promise of strange developments. It could not be supposed that the ether, if its reality were once admitted, existed only to convey through interstellar regions the vibrations which happen to stimulate the optic nerve of man. Invented originally to fulfil this function, to this it could never be confined. And accordingly, as everyone now knows, things which, from the point of view of sense-perception, are as distinct as light and radiant heat, and things to which sense perception makes no response, like the electric waves of wireless telegraphy,[2] intrinsically differ, not in kind, but in magnitude alone.

This, however, is not all, nor nearly all. If we jump over the century

[1] The hypothesis of an ether was, of course, not new. But before Young and Fresnel it cannot be said to have been established.

[2] First known through the theoretical work of Maxwell and the experiments of Herz.

which separates 1804 from 1904, and attempt to give in outline the world-picture as it now presents itself to some leaders of contemporary speculation, we shall find that in the interval it has been modified, not merely by such far-reaching discoveries as the atomic and molecular composition of ordinary matter, the kinetic theory of gases, and the laws of the conservation and dissipation of energy, but by the more and more important part which electricity and the ether occupy in any representation of ultimate physical reality.

Electricity was no more to the natural philosophers in the year 1700 than the hidden cause of an insignificant phenomenon.[1] It was known, and had long been known, that such things as amber and glass, when 'electrified' by friction, could be made to attract light objects brought into their neighbourhood; yet it was about fifty years before the effects of electricity were perceived in the thunderstorm. It was about 100 years before it was detected in the form of a current. It was about 120 years before it was connected with magnetism; about 170 years before it was connected with light and ethereal radiation.

But to-day there are those who regard gross matter, the matter of everyday experience, as the mere appearance of which electricity is the physical basis; who think that the elementary atom of the chemist, itself far beyond the limits of direct perception, is but a connected system of monads or sub-atoms which are not electrified matter, but are electricity itself; that these systems differ in the number of monads which they contain, in their arrangement, and in their motion relative to each other and to the ether; that on these differences, and on these differences alone, depend the various qualities of what have hitherto been regarded as indivisible and elementary atoms; and that while in most cases these atomic systems may maintain their equilibrium for periods which, compared with such astronomical processes as the cooling of a sun, may seem almost eternal, they are not less obedient to the law of change than the everlasting heavens themselves.

But if gross matter be a grouping of atoms, and if atoms be systems of electrical monads, what are these electrical monads? It may be that, as Professor Larmor has suggested, they are but a modification of the universal ether, a modification roughly comparable to a knot in a medium which is inextensible, incompressible, and continuous. But whether this final unification be accepted or not, it is certain that these monads cannot be considered *apart* from the ether. It is on their interaction with the ether that their qualities depend; and without the ether an electric theory of matter is impossible.

Surely we have here a very extraordinary revolution. Two centuries ago electricity seemed but a scientific toy. It is now thought by many to constitute the reality of which matter is but the sensible expression.

[1] The modern history of electricity begins with Gilbert, but I have throughout confined my observations to the post-Newtonian period.

It is but a century ago that the title of an ether to a place among the constituents of the universe was authentically established. It seems possible now that it may be the stuff out of which that universe is wholly built. Nor are the collateral inferences associated with this view of the physical world less surprising. It used, for example, to be thought that mass was an original property of matter, neither capable of explanation nor requiring it ; in its nature essentially unchangeable, suffering neither augmentation nor diminution under the stress of any forces to which it could be subjected ; unalterably attached to each material fragment, howsoever much that fragment might vary in its appearance, its bulk, its chemical or its physical condition.

But if the new theories be accepted, these views must be revised. Mass is not only explicable, it is actually explained. So far from being an attribute of matter considered in itself, it is due, as I have said, to the relation between the electrical monads of which matter is composed and the ether in which they are bathed. So far from being unchangeable, it changes, when moving at very high speeds, with every change in its velocity.

Perhaps, however, the most impressive alteration in our picture of the universe required by these new theories is to be sought in a different direction. We have all, I suppose, been interested in the generally accepted views as to the origin and development of suns with their dependent planetary systems ; and the gradual dissipation of the energy which during this process of concentration has largely taken the form of light and radiant heat. Follow out the theory to its obvious conclusions, and it becomes plain that the stars now visibly incandescent are those in mid-journey between the nebulæ from which they sprang and the frozen darkness to which they are predestined. What, then, are we to think of the invisible multitude of the heavenly bodies in which this process has been already completed ? According to the ordinary view we should suppose them to be in a state where all possibilities of internal movement were exhausted. At the temperature of interstellar space their constituent elements would be solid and inert ; chemical action and molecular movement would be alike impossible, and their exhausted energy could obtain no replenishment unless they were suddenly rejuvenated by some celestial collision, or travelled into other regions warmed by newer suns.

This view must, however, be profoundly modified if we accept the electric theory of matter. We can then no longer hold that if the internal energy of a sun were as far as possible converted into heat either by its contraction under the stress of gravitation, or by chemical reactions between its elements, or by any other inter-atomic force ; and that were the heat so generated to be dissipated (as in time it must be) through infinite space, its whole energy would be exhausted. On the contrary, the amount thus lost would be absolutely insignificant compared with what remained stored up within the separate atoms. The system in its corporate capacity would become bankrupt—the wealth of its individual

constituents would be scarcely diminished. They would lie side by side, without movement, without chemical affinity; yet each one, howsoever inert in its external relations, the theatre of violent motions, and of powerful internal forces.

Or, put the same thought in another form: When the sudden appearance of some new star in the telescopic field gives notice to the astronomer that he, and perhaps, in the whole universe, he alone, is witnessing the conflagration of a world, the tremendous forces by which this far-off tragedy is being accomplished must surely move his awe. Yet not only would the members of each separate atomic system pursue their relative course unchanged, while the atoms themselves were thus riven violently apart in flaming vapour, but the forces by which such a world is shattered are really negligible compared with those by which each atom of it is held together.

In common, therefore, with all other living things we seem to be practically concerned chiefly with the feebler forces of Nature, and with energy in its least powerful manifestations. Chemical affinity and cohesion are on this theory no more than the slight residual effects of the internal electrical forces which keep the atom in being. Gravitation, though it be the shaping force which concentrates nebulæ into organised systems of suns and satellites, is trifling compared with the attractions and repulsions with which we are familiar between electrically charged bodies; while these again sink into insignificance beside the attractions and repulsions between the electric monads themselves. The irregular molecular movements which constitute heat, on which the very possibility of organic life seems absolutely to hang, and in whose transformations applied science is at present so largely concerned, cannot rival the kinetic energy stored within the molecules themselves. This prodigious mechanism seems outside the range of our immediate interests. We live, so to speak, merely on its fringe. It has for us no promise of utilitarian value. It will not drive our mills; we cannot harness it to our trains. Yet not less on that account does it stir the intellectual imagination. The starry heavens have from time immemorial moved the worship or the wonder of mankind. But if the dust beneath our feet be indeed compounded of innumerable systems, whose elements are ever in the most rapid motion, yet retain through uncounted ages their equilibrium unshaken, we can hardly deny that the marvels we directly see are not more worthy of admiration than those which recent discoveries have enabled us dimly to surmise.

II.

Now whether the main outlines of the world-picture which I have just imperfectly presented to you be destined to survive, or whether in their turn they are to be obliterated by some new drawing on the scientific palimpsest, all will, I think, admit that so bold an attempt to unify

physical nature excites feelings of the most acute intellectual gratification. The satisfaction it gives is almost æsthetic in its intensity and quality. We feel the same sort of pleasurable shock as when from the crest of some melancholy pass we first see far below us the sudden glories of plain, river, and mountain. Whether indeed this vehement sentiment in favour of a simple universe has any theoretical justification, I will not venture to pronounce. There is no *à priori* reason that I know of for expecting that the material world should be a modification of a single medium, rather than a composite structure built out of sixty or seventy elementary substances, eternal and eternally different. Why, then, should we feel content with the first hypothesis and not with the second? Yet so it is. Men of science have always been restive under the multiplication of entities. They have eagerly watched for any sign that the different chemical elements own a common origin, and are all compounded out of some primordial substance. Nor, for my part, do I think such instincts should be ignored. John Mill, if I rightly remember, was contemptuous of those who saw any difficulty in accepting the doctrine of 'action at a distance.' So far as observation and experiment can tell us, bodies *do* actually influence each other at a distance; and why should they not? Why seek to go behind experience in obedience to some *à priori* sentiment for which no argument can be adduced? So reasoned Mill, and to his reasoning I have no reply. Nevertheless, we cannot forget that it was to Faraday's obstinate disbelief in 'action at a distance' that we owe some of the crucial discoveries on which both our electric industries and the electric theory of matter are ultimately founded. While at this very moment physicists, however baffled in the quest for an explanation of gravity, refuse altogether to content themselves with the belief, so satisfying to Mill, that it is a simple and inexplicable property of masses acting on each other across space.

These obscure intimations about the nature of reality deserve, I think, more attention than has yet been given to them. That they exist is certain; that they modify the indifferent impartiality of pure empiricism can hardly be denied. The common notion that he who would search out the secrets of Nature must humbly wait on experience, obedient to its slightest hint, is but partly true. This may be his ordinary attitude; but now and again it happens that observation and experiment are not treated as guides to be meekly followed, but as witnesses to be broken down in cross-examination. Their plain message is disbelieved, and the investigating judge does not pause until a confession in harmony with his preconceived ideas has, if possible, been wrung from their reluctant evidence.

This proceeding needs neither explanation nor defence in those cases where there is an apparent contradiction between the utterances of experience in different connections. Such contradictions must of course be reconciled, and science cannot rest until the reconciliation is effected.

The difficulty only arises when experience apparently says one thing and scientific instinct persists in saying another. Two such cases I have already mentioned; others will easily be found by those who care to seek. What is the origin of this instinct, and what its value; whether it be a mere prejudice to be brushed aside, or a clue which no wise man would disdain to follow, I cannot now discuss. For other questions there are, not new, yet raised in an acute form by these most modern views of matter, on which I would ask your indulgent attention for yet a few moments.

III.

That these new views diverge violently from those suggested by ordinary observation is plain enough. No scientific education is likely to make us, in our unreflective moments, regard the solid earth on which we stand, or the organised bodies with which our terrestrial fate is so intimately bound up, as consisting wholly of electric monads very sparsely scattered through the spaces which these fragments of matter are, by a violent metaphor, described as 'occupying.' Not less plain is it that an almost equal divergence is to be found between these new theories and that modification of the common-sense view of matter with which science has in the main been content to work.

What was this modification of common sense? It is roughly indicated by an old philosophic distinction drawn between what were called the 'primary' and the 'secondary' qualities of matter. The primary qualities, such as shape and mass, were supposed to possess an existence quite independent of the observer; and so far the theory agreed with common sense. The secondary qualities, on the other hand, such as warmth and colour, were thought to have no such independent existence, being, indeed, no more than the resultants due to the action of the primary qualities on our organs of sense-perception; and here, no doubt, common sense and theory parted company.

You need not fear that I am going to drag you into the controversies with which this theory is historically connected. They have left abiding traces on more than one system of philosophy. They are not yet solved. In the course of them the very possibility of an independent physical universe has seemed to melt away under the solvent powers of critical analysis. But with all this I am not now concerned. I do not propose to ask what proof we have that an external world exists, or how, if it does exist, we are able to obtain cognisance of it. These may be questions very proper to be asked by philosophy; but they are not proper questions to be asked by science. For, logically, they are antecedent to physical science, and we must reject the sceptical answers to both of them before any such science becomes possible at all. My present purpose requires me to do no more than observe that, be this theory of the primary and secondary qualities of matter good or bad, it is the one on which, as a matter of fact, science has in the main proceeded. It was with matter thus

conceived that Newton experimented. To it he applied his laws of motion; of it he predicated universal gravitation. Nor was the case greatly altered when science became as much preoccupied with the movements of molecules as it was with those of planets. For molecules and atoms, whatever else might be said of them, were at least pieces of matter, and, like other pieces of matter, possessed those 'primary' qualities supposed to be characteristic of all matter, whether found in large masses or in small.

But the electric theory which we have been considering carries us into a new region altogether. It does not confine itself to accounting for the secondary qualities by the primary, or the behaviour of matter in bulk by the behaviour of matter in atoms; it analyses matter, whether molar or molecular, into something which is not matter at all. The atom is now no more than the relatively vast theatre of operations in which minute monads perform their orderly evolutions; while the monads themselves are not regarded as units of matter, but as units of electricity; so that matter is not merely explained, but is explained away.

Now the point to which I desire to call attention is not to be sought in the great divergence between matter as thus conceived by the physicist and matter as the ordinary man supposes himself to know it, between matter as it is perceived and matter as it really is, but to the fact that the first of these two quite inconsistent views is wholly based on the second.

This is surely something of a paradox. We claim to found all our scientific opinions on experience; and the experience on which we found our theories of the physical universe is our *sense-perception* of that universe. That *is* experience; and in this region of belief there is no other. Yet the conclusions which thus profess to be entirely founded upon experience are to all appearance fundamentally opposed to it; our knowledge of reality is based upon illusion, and the very conceptions we use in describing it to others, or in thinking of it ourselves, are abstracted from anthropomorphic fancies, which science forbids us to believe and Nature compels us to entertain.

We here touch the fringe of a series of problems with which inductive logic ought to deal; but which that most unsatisfactory branch of philosophy has systematically ignored. This is no fault of men of science. They are occupied in the task of making discoveries, not in that of analysing the fundamental presuppositions which the very possibility of making discoveries implies. Neither is it the fault of transcendental metaphysicians. Their speculations flourish on a different level of thought; their interest in a philosophy of nature is lukewarm; and howsoever the questions in which they are chiefly concerned be answered, it is by no means certain that the answers will leave the humbler difficulties at which I have hinted either nearer to or further from a solution. But though men of science and idealists stand acquitted, the same can hardly be said of empirical philosophers. So far from solving

the problem involved in the attempt to extract knowledge from experience, they seem scarcely to have understood that there was any such problem to be solved. Led astray by a misconception to which I have already referred; believing that science was concerned only with (so-called) 'phenomena,' that it had done all that it could be asked to do if it accounted for the sequence of our individual sensations, that it was concerned only with the 'laws of Nature,' and not with the inner character of physical reality; disbelieving, indeed, that any such physical reality does in truth exist;—it has never felt called upon seriously to consider what are the actual methods by which science attains its results, and how those methods are to be justified. If anyone, for example, will take up Mill's logic, with its 'sequences and co-existences between phenomena,' its 'method of difference,' its 'method of agreement,' and the rest; if he will then compare the actual doctrines of science with this version of the mode in which those doctrines have been arrived at, he will soon be convinced of the exceedingly thin intellectual fare which has so often been served out to us under the imposing title of Inductive Theory.

There is an added emphasis given to these reflections by a train of thought which has long interested me, though I acknowledge that it never seems to have interested anyone else. Observe, then, that in order of logic sense-perceptions supply the premisses from which we draw all our knowledge of the physical world. It is they which tell us there *is* a physical world; it is on their authority that we learn its character. But in order of causation they are effects due (in part) to the constitution of our organs of sense. What we see depends not merely on what there is to be seen, but on our eyes. What we hear depends not merely on what there is to hear, but on our ears. Now, eyes and ears, and all the mechanism of perception, have, according to accepted views, been evolved in us and our brute progenitors by the slow operation of Natural Selection. And what is true of sense-perception is of course also true of the intellectual powers which enable us to erect upon the frail and narrow platform which sense-perception provides, the proud fabric of the sciences.

Now Natural Selection only works through utility. It encourages aptitudes useful to their possessor or his species in the struggle for existence, and, for a similar reason, it is apt to discourage useless aptitudes, however interesting they may be from other points of view, because, being useless, they are probably burdensome.

But it is certain that our powers of sense-perception and of calculation were fully developed ages before they were effectively employed in searching out the secrets of physical reality—for our discoveries in this field are the triumphs but of yesterday. The blind forces of Natural Selection which so admirably simulate design when they are providing for a present need, possess no power of prevision, and could never, except by accident, have endowed mankind, while in the making, with a physiological or mental outfit adapted to the higher physical investigations.

So far as natural science can tell us, every quality of sense or intellect which does *not* help us to fight, to eat, and to bring up children, is but a by-product of the qualities which *do*. Our organs of sense-perception were not given us for purposes of research; nor was it to aid us in meting out the heavens or dividing the atom that our powers of calculation and analysis were evolved from the rudimentary instincts of the animal.

It is presumably due to these circumstances that the beliefs of all mankind about the material surroundings in which it dwells are not only imperfect but fundamentally wrong. It may seem singular that down to, say, five years ago, our race has, without exception, lived and died in a world of illusions; and that its illusions, or those with which we are here alone concerned, have not been about things remote or abstract, things transcendental or divine, but about what men see and handle, about those 'plain matters of fact' among which common sense daily moves with its most confident step and most self-satisfied smile. Presumably, however, this is either because too direct a vision of physical reality was a hindrance, not a help, in the struggle for existence; because falsehood was more useful than truth; or else because with so imperfect a material as living tissue no better results could be attained. But if this conclusion be accepted, its consequences extend to other organs of knowledge besides those of perception. Not merely the senses, but the intellect, must be judged by it; and it is hard to see why evolution, which has so lamentably failed to produce trustworthy instruments for obtaining the raw material of experience, should be credited with a larger measure of success in its provision of the physiological arrangements which condition reason in its endeavours to turn experience to account.

Considerations like these, unless I have compressed them beyond the limits of intelligibility, do undoubtedly suggest a certain inevitable incoherence in any general scheme of thought which is built out of materials provided by natural science alone. Extend the boundaries of knowledge as you may; draw how you will the picture of the universe; reduce its infinite variety to the modes of a single space-filling ether; re-trace its history to the birth of existing atoms; show how under the pressure of gravitation they became concentrated into nebulæ, into suns, and all the host of heaven; how, at least in one small planet, they combined to form organic compounds; how organic compounds became living things; how living things, developing along many different lines, gave birth at last to one superior race; how from this race arose, after many ages, a learned handful, who looked round on the world which thus blindly brought them into being, and judged it, and knew it for what it was: perform, I say, all this, and though you may indeed have attained to science, in nowise will you have attained to a self-sufficing system of beliefs. One thing at least will remain, of which this long-drawn sequence of causes and effects gives no satisfying explanation; and that

is knowledge itself. Natural science must ever regard knowledge as the product of irrational conditions, for in the last resort it knows no others. It must always regard knowledge as rational, or else science itself disappears. In addition, therefore, to the difficulty of extracting from experience beliefs which experience contradicts, we are confronted with the difficulty of harmonising the pedigree of our beliefs with their title to authority. The more successful we are in explaining their origin, the more doubt we cast upon their validity. The more imposing seems the scheme of what we know, the more difficult it is to discover by what ultimate criteria we claim to know it.

Here, however, we touch the frontier beyond which physical science possesses no jurisdiction. If the obscure and difficult region which lies beyond is to be surveyed and made accessible, philosophy, not science, must undertake the task. It is no business of this Society. We meet here to promote the cause of knowledge in one of its great divisions; we shall not help it by confusing the limits which usefully separate one division from another. It may perhaps be thought that I have disregarded my own precept; that I have wilfully overstepped the ample bounds within which the searchers into Nature carry on their labours. If it be so, I can only beg your forgiveness. My first desire has been to rouse in those who, like myself, are no specialists in physics, the same absorbing interest which I feel in what is surely the most far-reaching speculation about the physical universe which has ever claimed experimental support; and if in so doing I have been tempted to hint my own personal opinion, that as Natural Science grows it leans more, not less, upon a teleological interpretation of the universe, even those who least agree may perhaps be prepared to pardon.

REPORTS

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Investigation of the Upper Atmosphere by Means of Kites in co-operation with a Committee of the Royal Meteorological Society.—Third Report of the Committee, consisting of Dr. W. N. Shaw (*Chairman*), Mr. W. H. Dines (*Secretary*), Mr. D. Archibald, Mr. C. Vernon Boys, Dr. A. Buchan, Dr. R. T. Glazebrook, Dr. H. R. Mill, *and* Professor A. Schuster. (*Drawn up by the Chairman and Secretary.*)

The Committee have acted throughout in conjunction with the Committee of the Royal Meteorological Society.

Since the date of the last report an account of the observations made in the summer of 1903 has been communicated to the Royal Meteorological Society and published in their 'Quarterly Journal.'

Winter Observations.

In the interval between the meeting of the Association at Southport and the beginning of June experimental observations have been made at Oxshott; kites, of which various details have been altered, have been sent up almost every day on which the wind-force equalled or exceeded six on the Beaufort scale. The object of these experiments was to ascertain if the behaviour of the kites could be improved by alteration of shape, size, &c., more particularly with regard to uniformity of pull and stability in winds of varying force.

As regards the first of these qualities considerable improvement has been effected by arrangements which will be described subsequently.

Instruments.

A new form of meteorograph has been designed for kite experiments by which the records of pressure, temperature, and humidity are traced upon a revolving disc of paper instead of a drum.

The pressure is indicated by the variation of capacity of an aneroid box of thin metal containing air. This needs a temperature correction to give the actual pressure, and the necessary correction is obtained from the temperature trace. Temperature is recorded by the expansion of ether contained in a coil of thin brass tube, terminating at one end in a small aneroid box, the variation in the position of the lid indicating the

changes of temperature by direct multiplication with the aid of a single lever.

The humidity is given by the expansion and contraction of a bundle of hairs in the usual way. This apparatus was described by Mr. Dines for 'Symons's Meteorological Magazine' for July. One of its advantages for kite work is the stability of the pen levers due to the more powerful controlling forces. Another important advantage is that the apparatus is comparatively cheap. It is made by Mr. Hicks, of Hatton Garden.

Ascents in connection with the International Aëronautical Investigation.

From the beginning of February till June ascents were made at Oxshott on every day specified by the President of the International Aëronautical Committee unless the wind was too light for work with kites.

Ascents from H.M.S. 'Seahorse.'

As reported last year, an application made by the Royal Society to the Admiralty for the loan of a vessel for experiments with kites became inoperative in consequence of the accident to the ship which their lordships intended to place at the disposal of the Committee for the purpose. At the desire of the Royal Meteorological Society the Royal Society renewed the application for the loan of a vessel with a view to experiments in the summer, and their lordships assigned H.M.S. 'Seahorse,' a special service vessel of 600 tons and 1,000 horse-power, for the service, under the command of Staff-Captain F. W. A. Crooke, R.N., for six weeks from the middle of June. Mr. Dines visited Portsmouth to make preliminary arrangements, and the 'Seahorse' arrived at Crinan on June 16. The fitting of the winding engine was completed on June 18, and the operations commenced on Monday, June 20, and were continued daily until July 28, with the exception of Sundays and the three days, July 9, 11, and 12, when the vessel was at Oban for the purpose of coaling. The approximate heights of the several ascents were as follows:—

Date	Height reached	Date	Height reached
	Feet		Feet
June 20	3,250	July 8	5,000
,, 21	4,000	,, 13	8,500
,, 22	5,340	,, 14	1,750
,, 23	3,320	,, 15	8,060
,, 24	4,100	,, 16	6,050
,, 25	3,750		6,760[1]
,, 27	2,300	,, 18	1,200
,, 28	7,300	,, 19	4,200
,, 29	4,900	,, 20	2,680
,, 30	5,600	,, 21	5,500
July 1	5,500	,, 22	5,900
,, 2	4,400	,, 23[2]	—
,, 4	6,300	,, 25	5,310
,, 5	7,200	,, 26	5,280
,, 6	5,300	,, 27[2]	—
,, 7	7,350	,, 28	8,000

[1] Afternoon.

[2] No ascent owing to want of wind. Persistently calm weather prevailed on and after July 18.

The Committee take this opportunity of recording their thanks to the Royal Society for their action in the matter, to the Lords of the Admiralty for the loan of the 'Seahorse,' and to Staff-Captain Crooke and the officers and men of his vessel for the manner in which they contributed to the carrying out of the observations. An account of the results of the experiments will be published later.

Proposed Observations on S.S. 'Helga.'

In the course of correspondence with Mr. E. W. L. Holt, of the Fishery Branch of the Irish Board of Agriculture Technical Instruction, Dr. Shaw learned that there was a prospect of occasional kite observations on board the s.s. 'Helga,' belonging to the board, provided that the Department was not called upon to defray the expenses of the necessary apparatus and materials. Dr. Shaw reported the matter to the Committee, and reported, further, that if the Committee were willing to supply apparatus and gear for the experiments on the 'Helga' the Meteorological Council were prepared to make arrangements with Mr. Dines to initiate the experiments and explain the method of working the apparatus.

Of the contribution of 200*l.* from the Government Grant Fund made last year for the purpose of hiring a vessel a sum of about 90*l.* remained; and as the loan of H.M.S. 'Seahorse' obviated the necessity for the further hiring of a vessel, it was suggested that the unexpended balance of the fund might be used to provide the apparatus. After communicating with the Royal Society upon the matter the Committee decided to adopt the suggestion, and Mr. Dines made ready a duplicate set of apparatus, which will be mounted on board the 'Helga' as soon as an opportunity offers for commencing experiments on that vessel.

The funds appropriated to the use of the Committee during the year have been :—

	£
Balance of Government Grant Fund left over from last year .	90
British Association Grant made at Southport	50
Anonymous Contribution by a Member of the Council of the Royal Meteorological Society	25

Provision for Continuation of the Experiments.

The Committee of Section A of the British Association passed a resolution desiring the Council to take steps to urge upon the Government the provision of means for co-operating in an organised union with the Continental nations and with India and America in the investigation of the upper air by means of balloons and kites. The decision of the Government with regard to the matter is nevertheless intimately connected with the action intended with regard to the Report of the Meteorological Grant Committee of the Treasury. The Committee's report was published in June, and refers in favourable terms to the proposed investigation, but suggests no specific grant for the purpose. The action of the Government with regard to the finding of the report has not yet been made known.

Nothing is therefore ascertained as to the prospects of an investigation of the upper air of this country upon an official basis. In the meantime Mr. Dines is likely to be able with the apparatus in hand to obtain kite observations on the fixed days of the Meteorological Committee, and to make further investigations with regard to improvements

of the kites and apparatus. With regard to the latter an easy means of calibrating the meteorograph is required, and this involves the use of a suitable air-tight inclosure which might be used for similar operations in future. The cost of such an apparatus is estimated at 25*l.*

The Committee therefore ask for reappointment, with a grant of 40*l.*

Report on the Theory of Point-groups.[1]—PART IV.
By FRANCES HARDCASTLE, *Cambridge.*

§ 10. **1857–1873.** The rise and development of the theory of algebraic functions has been described by Brill and Noether in a masterpiece of German erudition.[2] The whole of the fifth and sixth sections of this work, as well as large portions of other sections, treat, historically and critically, of matters more or less relevant to the theory of point-groups. It would be impracticable to deal thoroughly with such a mass of material within the limits of this Report. Some account of certain publications of this period will, however, indicate how the theory of functions came to be connected with the theory of higher plane curves, a connection which is the origin of the theory of point-groups. And as a preliminary to this, the following section deals very briefly with Riemann's contribution to the ideas which gave rise to this theory.

At the very end of the eighteenth century, two years before the birth of Plücker and five years before that of Jacobi, Gauss, then in his twenty-second year, put forward a strictly rigorous proof of the fundamental theorem of algebra. In this dissertation[3] the position of a point in the plane was taken, for the first time, as the geometrical interpretation of a single complex variable, in contrast to the Cartesian plan, which, confining the attention to real quantities, had associated two independent variables with each point. By this interpretation the first step was taken towards the connection of the theory of functions with the theory of higher plane curves; for, fifty-two years later, this plane of the complex variable was made the foundation of the ingenious structure commonly known as a 'Riemann surface.' The conception of a many-sheeted surface spread over the plane, upon which the complex variable is free to move, and in which the sheets are connected by interpenetration of one another in a manner which it is impossible to construct in the concrete, but which in the imagination affords a perfect representation of the 'branching' of a many-valued function, each sheet being associated with one branch of the function, and melting into another sheet round a point at which, for one and the same value of the variable, two branches coincide—this conception, by means of which the many-valued function is transformed into a one-valued function of the position of the variable on the surface, is due to Riemann (1826–1866), who first described such a surface in his 'Inaugural Dissertation,'

[1] Parts I., II., and III. appeared in the *Brit. Assoc. Reports* for 1900, 1902, 1903.

[2] Brill and Noether, 'Die Entwicklung der Theorie der algebraischen Functionen in älterer und neuerer Zeit' (*Jahresber. d. deutschen Math. Ver.* vol. iii. (1894), pp. 109–565).

[3] 'Demonstratio nova theorematis, omnem functionem algebraicam rationalem integram unius variabilis in factores reales primi vel secundi gradus resolvi posse,' Helmstadt, 1799; Gauss, *Werke,* vol. iii. 1876, pp. 1–30.

published in 1851.[1] This surface is an essential feature of Riemann's method; the results in the theory of functions which he obtained are all intimately connected with its use; and it is as a consequence of this fact that the possibility of the transference of these results into the theory of higher plane curves naturally presented itself to his readers. A Riemann surface is, in its original state, 'multiply connected,' *i.e.*, it cannot be bounded by one continuous curve; its dissection into a 'simply connected' surface, bounded by one continuous curve, is effected by means of 'cross-cuts.' In one of the opening sections of his 'Theory of Abelian Functions'[2] Riemann takes the number of these cross-cuts for any given surface to be $2p$, and this assumption provides the original definition of the number p, a number which reappears on every page of this memoir, and whose importance is marked in § 11 by the establishment of its permanence under bi-rational transformation of the equation $F(s, z) = 0$, associated with the given Riemann surface. In § 12 Riemann further pointed out that all algebraic equations can be divided into classes: those of the same class are derivable from each other by bi-rational transformation, and are characterised by the value of p. This classification is of great importance; for subsequently, when the number p has been identified with a purely geometrical property of a curve, it is shown that, starting from this as a definition, p is permanent under a bi-rational transformation of the curve; and the standpoint of projective geometry, from which curves are classified according to their orders, is almost entirely replaced in the theory of point-groups by the standpoint of bi-rational transformation, in which a curve is classified according to the value of p.

Riemann regarded all the functions with which he dealt not, as other writers had done, from the point of view of the actual functional form they possess, but as defined by certain properties.[3] Among these properties is the existence of infinities of given orders at given points of the Riemann surface, and of given 'moduli of periodicity' at the $2p$ cross-cuts. The simplest case is that in which the function has no infinities, but only moduli of periodicity: these were called by Riemann 'integrals of the first kind,' and, from the fact that there are $2p$ cross-cuts, he showed that there are exactly p linearly independent integrals of this kind on a surface.[4] He next discussed integrals of the 'second' and of the 'third' kinds, which have respectively algebraic and logarithmic infinities, and then proceeded to form an algebraic function by means of a sum of integrals of the first and second kinds, together with an additive constant, this sum being subject to the condition that the moduli of periodicity should vanish.[5] And, by counting the constants in the equations which express this condition, he found that, after the m infinities of an algebraic function have been chosen on the surface, there will always remain precisely $m-p+1$ arbitrary constants (including the additive constant) in its expression.[6] This result was corrected seven years later by Roch (1839–1866), who pointed out that under certain conditions the number of arbitrary

[1] 'Grundlagen für eine allgemeine Theorie der Functionen einer veränderlichen complexen Grosse,' Inaugural-Dissertation, Göttingen, 1851, *Ges. Werke*, pp. 3–47.

[2] 'Theorie der Abel'schen Functionen,' Crelle, vol. liv., 1857; *Ges. Werke*, 2nd edit. 1892, pp. 88–144.

[3] *Loc. cit.* § 3.

[4] *Loc. cit.* § 4.

[5] *Loc. cit.* § 5.

[6] *Loc. cit.* § 5.

constants is increased. The theorem in which he formulated the true state of the case will be enunciated later on, after a brief summary of some more of Riemann's results.

After showing that an algebraic function, s, with m infinities on the surface, is the root of an irreducible equation of the nth degree whose coefficients are integral functions of the mth degree in z, the complex variable—in other words, after showing that there is an equation, $F(\overset{n}{s}, \overset{m}{z})=0$, which is so associated with the surface that as z moves over its whole extent, s is a one-valued function of its position with m simple infinities—Riemann considered the question of the determination of the 'branch-points' of the surface from knowledge of the associated equation. The essential property of a branch-point is not only that two branches of the function coincide for a certain value of z, but that, as z moves round the branch point, these branches interchange their values.[1] This opens up the possibility that two branch-points may, as it were, destroy each other by coincidence; and, by expansion of $F(\overset{n}{s}, \overset{m}{z})=0$ at a point, Riemann showed that true branch-points only occur when $\frac{\partial F}{\partial s}=0$, but not $\frac{\partial F}{\partial z}$; or else when $\frac{\partial F}{\partial s}=0$, $\frac{\partial F}{\partial z}=0$, and $\frac{\partial^2 F \partial^2 F}{\partial s^2 \partial z^2}=\left(\frac{\partial F \,.\, \partial F}{\partial s \,.\, \partial z}\right)^2$; when $\frac{\partial F}{\partial s}=0$ and $\frac{\partial F}{\partial z}=0$, but $\frac{\partial^2 F \partial^2 F}{\partial s^2 \partial z^2} \neq \left(\frac{\partial F \,.\, \partial F}{\partial s \,.\, \partial z}\right)^2$ the branches do not interchange their values as z moves round the point. In the discussion of the r branch-points which may thus disappear, Riemann explicitly limits himself by assuming that when branch-points coincide it shall only be in pairs; he thus rules out altogether the cases in which $\frac{\partial F}{\partial s}=0$, $\frac{\partial F}{\partial z}=0$, and $\frac{\partial^2 F \,.\, \partial^2 F}{\partial s^2 \,.\, \partial z^2}=\left(\frac{\partial F \partial F}{\partial s \partial z}\right)$ when three branch-points coincide, two of them destroying each other. This limitation is, however, quite unnecessary, and in the subsequent adaptation of his results for the purposes of higher plane curves it was not adhered to.[2] Riemann used his determination of the number of arbitrary constants in the expression of an algebraic function of the surface to show that every algebraic function s' with m infinities, can be expressed as the quotient of two integral functions.[3] The number of arbitrary constants in such a quotient will be, as required, $m-p+1$, provided that both numerator and denominator vanish at the r points in which two branch-points destroy each other; and this condition is also required in order to ensure that s' should, in general, assume two different values at such a point, although s has only one value. Now $\frac{\partial w}{\partial z}$, the differential coefficient with respect to z of the integral of the first kind, is an algebraic function on the given surface, and it is infinite at the branch-points of the surface; moreover $\frac{\partial F}{\partial s}$ vanishes at the branch-points of the surface and at the r other points as well; hence the simplest expression as a quotient for $\frac{\partial w}{\partial z}$ is one in which the denominator is $\frac{\partial F}{\partial s}$; the numerator is then a function which Riemann denotes as

[1] *Loc. cit.* § 6. [2] See Clebsch, Crelle, vol. lxiii. p. 192. [3] *Loc. cit.* § 8.

$\phi(\overset{n-2}{s}, \overset{m-2}{z})$, and it also must vanish at the r points.[1] This function ϕ has, in general $(n-1)(m-1)-r$ arbitrary constants, a number which Riemann had previously shown[2] to be equal to p. There are, therefore, p linearly independent functions ϕ, which agrees with the former statement that there are p linearly independent integrals of the first kind. The function ϕ, which thus appears quite naturally in this expression for $\frac{\partial w}{\partial z}$, plays an important part in that portion of Riemann's work which, through its influence on the theory of higher plane curves, is connected with the theory of point-groups. It is characterised by the fact that it must vanish at the r fixed points on the surface where a pair of branch-points destroy each other; moreover, as Riemann went on to show, it has also $m(n-2)+n(m-2)-2r=2p-2$ other zeros which may be anywhere on the surface;[3] in contradistinction to the fixed zeros, common to all ϕ's, these latter are now often spoken of as *the moveable zeros of a ϕ-function.* Roch's correction of Riemann's enumeration of the number of arbitrary constants involved in the expression of an algebraic function on the surface—alluded to above—is concerned with this function ϕ, and his theorem is as follows:[4] 'If an algebraic function s' have m infinities on the surface associated with $F(\overset{n}{s}, \overset{m}{z})=0$, and if q functions ϕ, which are linearly independent of each other, vanish in these m points, then s' has $m-p+1+q$ arbitrary constants in its expression.'

This is the theorem known in the theory of functions as the Riemann-Roch theorem; transferred into the theory of higher plane curves it became part of a more general theorem, now usually spoken of as Brill and Noether's Theorem of Reciprocity. The latter, which is of fundamental importance for the theory of point-groups, was not taken from any theorem which had been explicitly stated in the theory of functions, but its enunciation was suggested by certain results obtained by Riemann in connection with the theta-functions.[5] These results are based upon the discussion of Abel's theorem, which occupies the last three sections of the first part of Riemann's 'Theory of Abelian Functions.' Part II. of this work is devoted to the theta-functions, but the actual results in which we are interested appear in a later memoir (1865) on the vanishing of the theta-functions.[6] A short account of these investigations will now be given in order to show how the first idea of a point-group arose.

Riemann was only directly concerned with Abel's theorem in so far as it applied to integrals of the first kind; he was in fact the first definitely to enunciate and prove it for this case, for in Abel's original discussion of the subject this case had been treated as a particular instance of the more general theorem for the three kinds of Abelian integrals, and the conditions under which the sum of the integrals reduces to a constant (*i.e.*, the case in question) are complicated, and involve possibilities which are excluded by Riemann's method of attacking the problem. This method, moreover, is readily applicable to the other cases, which, however, do not concern us here. The ϕ-function, which enters, as we have seen,

[1] *Loc. cit.* § 9. [2] *Loc. cit.* § 7. [3] *Loc. cit.* § 10.

[4] Roch, 'Ueber die Anzahl der willkürlichen Constanten in algebraischen Functionen,' Crelle, vol. lxiv. pp. 372–376 (1865).

[5] See Brill and Noether's *Bericht*, also *Mathematische Annalen*, vol. vii. p. 280.

[6] Riemann, 'Ueber das Verschwinden der Thetafunctionen,' Crelle, vol. lxv. 1866; *Ges. Werke*, pp. 212–224.

automatically into Riemann's expression for the differential of the integral of the first kind, is necessarily involved in his discussion of this particular case of Abel's theorem; it forms, indeed, the natural link between those results in the theta-functions already alluded to and Abel's theorem itself. Thus the theory of point-groups was originally provided with a purely transcendental foundation—the whole superstructure being based upon Abel's theorem—although, as will subsequently be seen, its true foundation is algebraical, and it can be rendered perfectly independent of transcendental considerations.

The basis of Riemann's proof of Abel's theorem is his division of algebraic functions into classes pertaining to the same Riemann surface. For this enables him to take ζ any rational function of s and z as the independent variable in w, an integral of the first kind on the surface associated with $F(\overset{n}{s}, \overset{m}{z})=0$. If, then, ζ has m infinities on the surface, $\frac{dw}{dz}$ is an m-valued algebraic function of ζ; and if $w^{(1)}, w^{(2)}, \ldots, w^{(m)}$ are the m-values of w for any one and the same value of ζ, $\sum_{k=1}^{k=m}\frac{dw^{(k)}}{dz}$ is a one-valued function of ζ whose integral is everywhere finite on the surface. This function, composed of the sum of m-integrals, is thus necessarily equal to a constant, and by proper choice of the path of integration can be easily shown to be zero; with the notation previously introduced by Riemann, we have

$$\text{(A)} \qquad \int\frac{\phi(s_1z_1)dz_1}{\frac{\partial F(s_1z_1)}{\partial s_1}}+\int\frac{\phi(s_2z_2)dz_2}{\frac{\partial F(s_2z_2)}{\partial s_2}}+\ldots\int\frac{\phi(s_mz_m)dz_m}{\frac{\partial F(s_mz_m)}{\partial s_m}}=0$$

where $(s_1z_1) \ldots (s_mz_m)$ are pairs of values of s, z, at which ζ assumes one and the same value.[1] This is Abel's theorem for integrals of the first kind. Its importance for the theory of point-groups lies in its establishment of a system of p differential equations formed by writing consecutively $\phi_1 \ldots \phi_p$ for ϕ in the left-hand side of equation A; these ϕ's being the p linearly independent numerators in Riemann's expressions for the p linearly independent integrals of the first kind. In discussing the integration of these equations Riemann introduces the notion of a system of quantities being *congruent*, with respect to certain moduli, *to another system*; the p quantities $(b_1 \ldots b_p)$, namely, are said to be congruent to the p quantities $(a_1 \ldots a_p)$ with respect to $2p$ systems of moduli, when $b_\pi=a_\pi+\sum_{r=1}^{2p}m_rk_\pi^{(r)}$ where $\pi=1 \ldots p$ and $m_1 \ldots m_{2p}$ are integers. The notation is $(b_1 \ldots b_p)\equiv(a_1 \ldots a_p)$.[2]

The necessity for this notation arises—although Riemann does not explicitly say so—where the paths of integration in equation (A) are arbitrary; the sign of equality in that equation must then be replaced by a sign of congruence.

In an earlier section (§ 10) of Part I. of the 'Theory of Abelian Functions' Riemann had shown that a rational function can be expressed as a quotient of two ϕ-functions provided that the number of its infinities be less than $p+1$. This result is obtained by counting constants in the

[1] Riemann's 'Theorie der Abel'schen Functionen,' § 14. [2] *Loc. cit.* § 15.

quotient $\frac{\phi^{(1)}}{\phi^{(2)}}$; the reasoning is somewhat obscure, and the number does not tally with the number of arbitrary constants previously found by the author; on the contrary, it agrees with Roch's more accurate formula, showing that, in certain cases at least, Riemann knew that his own needed modification. But, however this may be, the result itself is true, and its use in the integration of the p equations formed from equation (A) is of importance. For if ζ is expressible as the quotient $\frac{\chi}{\psi}$ (or, if $m<p+1$, as the quotient $\frac{\phi^{(1)}}{\phi^{(2)}}$), then $(s_1z_1)\ldots(s_mz_m)$ are the common roots of $F(\overset{n}{s},\overset{m}{z})=0$ and of $\zeta=\frac{\chi}{\psi}$ (or of $F(\overset{n}{s},\overset{m}{z})=0$ and $\zeta=\frac{\phi^{(1)}}{\phi^{(2)}}$). That is to say, $(s_1z_1)\ldots(s_mz_m)$ may be regarded as the common roots of $F=0$ and $\chi=\zeta\psi$ (or of $F=0$ and $\phi^{(1)}-\zeta\phi^{(2)}=0$), but they are roots which vary with ζ, not those which make $\chi=\psi=0$ (or $\phi^{(1)}=\phi^{(2)}=0$) independently of ζ. *When $m<p+1$, they are therefore* m *of the* 2p$-$2 *moveable zeros of a ϕ-function,* since $\phi^{(1)}-\zeta\phi^{(2)}$ obviously fulfils the necessary conditions which make it ϕ-function.[1] It is, of course, also possible, though not necessary, that even when $m>p+1$, ζ should be expressible as the quotient of two ϕ-functions, and in such cases, once more, $(s_1z_1)\ldots(s_mz_m)$ are m of the $2p-2$ moveable zeros of a ϕ-function.

Now Riemann shows that the p differential equations formed from equations (A) can be completely integrated, under certain conditions: first, when $m\leq p+1$ and ζ is perfectly general; next, when $m=p$, in which case ζ is necessarily expressible as the quotient of two ϕ-functions; and, lastly, when $m=2p-2$, provided that ζ *is* expressible as the quotient of two ϕ-functions. For, in the first case, if $m=p+1$, $\frac{1}{\zeta}$ has $p+1-p+1$, *i.e.*, *two* independent constants; it therefore depends upon *one* arbitrary parameter after its $p+1$ infinities have been chosen, and therefore s, z, which are $(p+1)$-valued functions of ζ, also depend only upon one parameter, when $\frac{1}{\zeta}$ has been chosen so that it becomes infinite (*i.e.*, $\zeta=0$) at the $p+1$ lower limits of the integrals; of the $p+1$ upper limits $(s_1z_1)\ldots(s_{p+1}z_{p+1})$ of the $p+1$ integrals connected by the p differential equations it is thus seen that only *one* can remain arbitrary under these conditions, and the system can therefore be completely integrated. If $m<p+1$ the reasoning only needs to be modified by considering that certain of the upper and lower limits coincide, whereby such integrals drop out from the equations. The solution of the p differential equations may then be written

$$\left(\sum_{\mu=1}^{\mu=p+1} w_1^{(\mu)},\ \sum_{1}^{p+1} w_2^{(\mu)}\ldots\sum_{1}^{p+1} w_p^{(\mu)}\right)\equiv(c_1\ldots c_p),$$

where $c_1\ldots c_p$ are constants which depend upon the choice of the lower limits of the integrals.[2]

In the second case, when $m=p$, ζ is necessarily of the form $\frac{\phi^{(1)}}{\phi^{(2)}}$, and now, by the Riemann-Roch formula, it has $p-p+1+1$, *i.e.*, two inde-

[1] *Loc. cit.* § 16. [2] *Loc. cit.* § 14.

pendent constants as before; the differential equations can be integrated, and $(s_1 z_1) \ldots (s_p z_p)$ are p of the $2p-2$ moveable zeros of a ϕ-function.

In the third case, since ζ is a quotient of two ϕ-functions, ζ has $2p-2-p+1+1=p$ independent constants, *i.e.*, it has $p-1$ arbitrary parameters, and thus, as Riemann states it, 'the problem of determining $p-1$ of the $2p-2$ quantities $(s_1 z_1) \ldots (s_{2p-2} z_{2p-2})$ in such a manner that they shall be functions of the remaining $p-1$ and shall satisfy the p differential equations

$$\sum_{1}^{2p-2} dw_{\pi}^{(\mu)} = c \text{ for } \pi = 1, \ldots p$$

is completely solved if the $2p-2$ quantities are the moveable zeros of a ϕ-function, and there is only one solution.' Such pairs of quantities are said to be *tied* by the equation $\phi=0$.[1] And the solution of the differential equations, with the notation introduced above, is

$$\left(\sum_{1}^{2p-2} w_1^{(k)}, \sum_{1}^{2p-2} w_2^{(k)} \ldots \sum_{1}^{2p-2} w_p^{(k)} \right) \equiv (c_1 \ldots c_p),$$

where c_μ only depends upon the additive constants in w_μ, *i.e.*, upon the lower limits of the integrals; or, in other words, the sum of the values which any one of the p linearly independent integrals of the first kind assumes at the $2p-2$ moveable zeros of a ϕ-function is congruent to a constant which only depends upon the lower limits of the integrals.

Part II. of Riemann's 'Theory of Abelian Functions' is, as has been said, devoted to the consideration of the theta-functions, which he defines thus:

$$\vartheta(v_1 \ldots v_p) = \left(\sum_{-\infty}^{+\infty} \right)^p e^{\left(\sum_{1}^{p} \right)^2 a_{\mu\mu'} m_\mu m_{\mu'} + 2\sum_{1}^{p} v_\mu m_\mu},$$

where the summations in the exponents are with respect to μ, μ', and that in the outer bracket with respect to $m_1 \ldots m_p$. The adoption of $u_1 \ldots u_p$ the p linearly independent integrals of the first kind, in place of the general arguments $v_1 \ldots v_p$ and of the moduli of periodicity of the u's in place of the constants $a_{\mu\mu'}$—an adoption which is duly justified by Riemann—makes, as he says, 'log ϑ a function of a single variable z, which when s, z resume their original values after an arbitrary continuous change in the position of z, is changed by linear functions of the u's.'[2] Thus ϑ is a one-valued function of p arguments, but of a single point on the Riemann surface, which point is the upper limit of each of the p integrals which appear in the arguments of ϑ. The notation employed by Riemann has not been adopted by all following writers, for he does not use the symbol of integration with upper and lower limits associated with it; he introduces instead a symbol of his own for the values of the integrals at the upper limits, and only mentions the lower limits in words. There is, for our purpose, a certain advantage in this notation, for it draws attention to the values of an integral u_μ at a certain set of points which form the different upper limits of the same integrand. Thus, if $\epsilon_1 \ldots \epsilon_m$ are the m points on the surface in which a rational function of s, z takes the same value, then, in Riemann's notation, $u_\mu^{(v)}$ is the value of u_μ (for $\mu=1, \ldots p$) at the point ϵ_v (for $v=1, \ldots m$), for

[1] *Loc. cit.* § 16. [2] *Loc. cit.* § 17.

which the values of s, z are s_v, z_v; in particular, if $\eta_1 \ldots \eta_p$ are the p zeros which every ϑ-function is shown to have, then $\alpha_\mu^{(v)}$ is the value of u_μ (for $\mu=1, \ldots p$) at the point η_v (for $v=1, \ldots p$) for which the values of s, z are σ_v, ζ_v.[1]

Moreover, if in the argument of the ϑ-function the integral $u_\mu^{(v)}$ or $\alpha_\mu^{(v)}$ occurs, it is possible, by allowing the point z_v or ζ_v (still defined as above) to be a variable point on the surface, to consider the ϑ-function as a function of z_v or of ζ_v instead of as a function of the quite unspecialised point z; this is important in connection with the identical vanishing of the ϑ-function. The introduction of additive constants $e_1 \ldots e_p$ into the arguments of the ϑ-function is another important feature of Riemann's discussion of the subject; for he shows [1] that in $\vartheta(\ldots u_\mu - e_\mu \ldots)$ it is always possible so to determine the lower limits of the integrals that $(\ldots e_\mu \ldots) \equiv \left(\ldots \sum_1^p \alpha_\mu^{(v)} \ldots\right)$ shall hold, and it is with *these* lower limits that he works. The establishment of this congruence between the additive constants of each integral and the sum of its p values at the p zeros of the ϑ-function leads to the preliminary discussion in § 23 and § 24 of the conditions under which a ϑ-function vanishes *identically*, i.e., for an *arbitrary* position of the variable point on the surface.

He first shows, in § 23, that if $(\ldots u_\mu - e_\mu \ldots) \equiv \left(\ldots -\sum_1^{p-1} \alpha_\mu^{(v)} \ldots\right)$ then the ϑ-function with these arguments vanishes identically, *i.e.*, for any arbitrary position of ζ; and, conversely, that if ϑ vanishes identically then each of its arguments $u_\mu - e_\mu$ must be congruent to a negative sum of the values of $p-1$ integrals at certain $p-1$ points $\eta_1 \ldots \eta_{p-1}$.[2] Now these $p-1$ points may be arbitrarily chosen, and we still have $\vartheta\left(\ldots -\sum_1^{p-1} \alpha_1^{(v)} \ldots\right)$ identically zero; and, since ϑ is an even function, this leads to $\vartheta\left(\ldots \sum_1^{p-1} \alpha_1^{(v)} \ldots\right)$ being also identically zero; whence by the above converse we are led to certain $p-1$ points $\eta_p \ldots \eta_{2p-2}$ such that $\left(\ldots \sum_1^{p-1} \alpha_1^{(v)} \ldots\right) \equiv \left(\ldots -\sum_p^{2p-2} \alpha_1^{(v)} \ldots\right)$, *i.e.*, to the congruence $\left(\ldots \sum_1^{2p-2} \alpha_1^{(v)} \ldots\right) \equiv (0, 0, \ldots 0)$. But this shows that the last $p-1$ points are dependent upon the position of the first $p-1$ points in such a manner that as the latter vary continuously we always have $\sum_1^{2p-2} d\alpha_\mu^{(v)} = 0$; and this system of differential equations is, as has been seen, always satisfied by the $2p-2$ moveable zeros of the ϕ-function (the lower limits are another set of moveable zeros, since $\zeta = \frac{\phi^{(1)}}{\phi^{(2)}}$, and when $\zeta = 0$, $\phi^{(1)}$ must $= 0$ but not $\phi^{(2)}$). Hence we have the important result that *when a ϑ-function vanishes identically its* p *zeros are tied by a ϕ-function.*

In § 24 a second important conclusion is derived from the fact that if

[1] *Loc. cit.* § 22.

[2] The precise determination of these $p-1$ points is as follows:—It is assumed that although $\vartheta(\ldots r_\mu \ldots)$ vanishes identically, yet that $\vartheta(\ldots u_\mu - \alpha_\mu^p + r_\mu \ldots)$ does *not* vanish identically where η_p is arbitrary—the remaining $p-1$ zeros of *this* ϑ are $\eta \ldots \eta_{p-1}$.

ϑ vanishes identically each of the arguments is congruent to the negative sum of the values of $p-1$ integrals at certain $p-1$ points; these points, namely, are assumed to be $p-1$ of the p points in which any rational function ζ takes one and the same value on the surface, and then with the notation explained above we have

$$\left(\ldots u_\mu^{(p)}-e_\mu\ldots\right)\equiv\left(\ldots-\sum_1^{p-1}u_\mu^{(\nu)}\ldots\right),$$

$$i.e.,\qquad \left(\ldots\sum_1^{p}u_\mu^{(\nu)}\ldots\right)\equiv\left(\ldots e_\mu\ldots\right).$$

Hence for all continuous variations of s_p, z_p we have $\sum_1^p du_\mu^{(\nu)}=0$, and therefore the p pairs of quantities s_μ, z_μ are p of the moveable zeros of $\phi=0$, where the remaining $p-2$ are fixed. And if $u^{(p+1)}\cdots u^{(2p-2)}$ be the values of u_μ at these $p-2$ fixed points we have $\left(\ldots\sum_1^{2p-2}u_\mu^{(\nu)}\ldots\right)\equiv(0,0,\ldots 0)$. Whence it follows that $(\ldots e_\mu\ldots)\equiv\left(\ldots-\sum_{p+1}^{2p-2}u_\mu\ldots\right)$. Which results are thus stated by Riemann: 'An arbitrary system of quantities $(\ldots e_\mu\ldots)$ is only congruent to one system of the form $\left(\ldots\sum_1^p \alpha_\mu^{(\nu)}\ldots\right)$ unless it is congruent to one of the form $\left(\ldots-\sum_1^{p-2}\alpha_\nu^{(\mu)}\ldots\right)$, in which case it is congruent to an infinite number of the first-mentioned form.'

It is in these results that we find the first suggestion of a *point-group*—that is, of a set of points on the Riemann surface which are chosen in some definite manner out of the set in which a rational function assumes one and the same value. Moreover, in the most general form into which Riemann threw these same results in his later memoir—now to be described—we find a conspicuous feature to be the reversible relationship which exists between a pair of point-groups in the two cases which he considers—a relationship, namely, concerning the number of points in each point-group which may be arbitrarily assumed. This relationship is intimately connected with the Riemann-Roch theorem—although Riemann himself was not concerned to point this out—and is a particular case of the Theorem of Reciprocity established by Brill and Noether.

The first two sections of the memoir on the vanishing of the ϑ-functions are occupied in putting the theorems of § 23 upon a more rigorous foundation by showing that it is always possible to take such arguments for a ϑ-function as to ensure that it does not vanish identically—in which case the results of § 23 and § 24 are true. The third section then goes on to establish these in a still more general form, by considering successive pairs of ϑ-functions with arguments that differ from each other in an analogous manner to those of $\vartheta(\ldots r_\mu\ldots)$ and $\vartheta(\ldots u_\mu-\alpha_\mu^p+r_\mu\ldots)$, of which the first vanishes identically, but not the second, and where r_μ itself is of increasing complexity. Thus a typical pair of ϑ-functions is

(1) $\vartheta(\ldots\alpha_r^{(p+1)}+\alpha_r^{(p)}+\ldots+\alpha_r^{(p-m+2)}-u_r^{(p-1)}-u_r^{(p-2)}-\ldots-u_r^{(p-m+1)}-e_r\ldots)$

and

(2) $\vartheta(\ldots\alpha_r^{(p+1)}+\quad\ldots+\alpha_r^{(p-m+1)}-u_r^{(p-1)}-u^{(p-r)}\quad\ldots-u_r^{(p-m)}\quad-e_r\ldots)$,

the first of which is assumed to vanish identically, while the second, whose arguments only differ by the addition of $\alpha_r^{(p-m+1)}-u_r^{(p-m)}$, does not. Since (2) does not vanish identically we have, by considering it as a

function of ζ_{p+1}, $(\ldots -a_r^p \ldots -a_r^{(p-m+1)}+u_r^{(p-1)}+\ldots+u_r^{(p-m)}+e_r \ldots)$ congruent to the sum of the values of all its p zeros; now the m points $\varepsilon_{p-1} \ldots \varepsilon_{p-m}$ are m of these zeros, since when $\zeta_{p+1}=z_{p-1} \ldots z_{p-m}$ in turn, we get a ϑ-function whose arguments are of the form of (1); let the $p-m$ other zeros be $\eta_1 \ldots \eta_{p-m}$, then the above congruence, when identical terms are removed from each side, becomes

$(\ldots -a_r^{(p-m+1)}- \ldots -a_r^p+e_r \ldots) \equiv (\ldots a_r^{(1)}+\ldots+a_r^{(p-m)} \ldots)$.

But again, by considering (2) as a function of z_{p-1}, we find that, ϑ being an even function, $(\ldots a_r^{(p+1)}+\ldots+a_r^{(p-m+1)}-u_r^{(p-2)}-\ldots-u_r^{(p-m)}-e_r \ldots)$ is congruent to the sum of its values at its p zeros; and that $m+1$ of these zeros are $\eta_{p+1} \ldots \eta_{p-m+1}$, since when $z_{p-1}=a^{(p+1)} \ldots a^{(p-m+1)}$ in turn we get a ϑ-function whose arguments are of the form (1); now let the $p-m-1$ other zeros be $\varepsilon_1 \ldots \varepsilon_{p-m-1}$, then the congruence which holds is $(\ldots -u_r^{(p-m)}-\ldots-u_r^{(p-2)}-\varepsilon_r \ldots) \equiv (\ldots u_r^{(1)}+\ldots+u_r^{(p-m-1)} \ldots)$.

We have thus shown that $(e_1 \ldots e_p) \equiv (a_r^{(1)} \ldots a_r^{(p)})$ and also to $(-u_r^{(1)} \ldots -u_r^{(p-2)})$, *i.e.*, that the point-groups composed of the p η's and those composed of the $p-2$ ε's are congruent to each other; and, moreover, that when m of the points η are arbitrary ($p-m$ being uniquely determined), then $m-1$ of the points ε are arbitrary (since $p-m-1$ of the $p-2$ are determinate). And it is easily seen that this relationship is reversible, *i.e.*, that if $m-1$ of the ε's are arbitrarily chosen, then m of the η's can be arbitrarily chosen. The $2p-2$ zeros of a ϕ-function have thus been divided into two point-groups, containing p and $p-2$ points respectively, and it has been shown that if m of the p points can be arbitrarily chosen, then $m-1$ of the $p-2$ points are also arbitrary, and *vice versa*.

A precisely similar line of argument applied to the conclusions of § 23 shows that the $2p-2$ zeros of a ϕ function may also be divided into two point-groups, each consisting of $p-1$ points, and that then, if m of one point-group are arbitrary, m of the other are also arbitrary.

The connection with the Riemann-Roch theorem is at once evident; for if in the first case dealt with above we assume that a rational function becomes infinite at p points, then, if m of these p points are arbitrary, the function has m arbitrary constants, and therefore, since by the Riemann-Roch theorem $m=p-p+1+q$, $q=m-1$, i.e., $m-1$, *different* ϕ functions can be drawn through them, which agrees with the number of ε's which have been shown to be arbitrary; and, conversely, if the number of infinities is $p-2$, and if $m-1$ only are arbitrary, the Riemann-Roch theorem shows that $m-1=p-2-p+1+q$, i.e., that $q=m$, which agree with the number of η's which may be chosen arbitrarily.

Magnetic Observations at Falmouth Observatory.—Report of the Committee, consisting of Sir W. H. PREECE *(Chairman)*, Dr. R. T. GLAZEBROOK *(Secretary)*, Professor W. G. ADAMS, Captain CREAK, Mr. W. L. FOX, Principal Sir ARTHUR RÜCKER, *and* Professor A. SCHUSTER, *appointed to co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.*

THE grant voted by the Association last year has been expended in carrying on the Magnetic Observations at Falmouth Observatory.

The apparatus at the Observatory was inspected by Mr. T. W. Baker

of the National Physical Laboratory in October last, and found to be working well. The results for the year 1903 have been printed in the Proceedings of the Cornwall Polytechnic Society and in the Report of the National Physical Laboratory for 1903. Dr. Chree is at present engaged in examining the Vertical Force Records for 1904, with a view to determining how best to treat these. They have not hitherto been worked out in full.

The records for the great magnetic storm of October 31 and November 1, 1903, were specially good, and have been reproduced in the Laboratory Report.

In view of the fact that the Kew magnets are very much disturbed and that the buildings at Eskdale Muir have only just been commenced, it is in the opinion of the Committee desirable that their work should be continued. They therefore recommend their reappointment, with a grant of 50*l.*

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Dr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, *and* G. CAREY FOSTER, Sir OLIVER J. LODGE, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors J. D. EVERETT, A. SCHUSTER, J. A. FLEMING, *and* J. J. THOMSON, Dr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Principal E. H. GRIFFITHS, Sir A. W. RÜCKER, Professor H. L. CALLENDAR, *and* Mr. GEORGE MATTHEY.

THE Committee desire to record their deep regret at the death of their colleague, Professor Everett, who had been a member of the Committee since 1881. He attended the meeting at which the present Report was considered. His work in connection with the C.G.S. system of units is of great importance and has proved of very real value to science.

The Committee are glad to report that during the year considerable progress has been made with the construction of the Ampère Balance. Mr. L. Oertling has constructed the weighing mechanism, which has, however, not yet been taken over by his Committee, and the electrical parts of the instrument are nearing completion in the workshops of the National Physical Laboratory. The following particulars of progress and of applied tests may be of interest.

1. *The weighing mechanism.*—The castings, rods, tubes, screws, &c., intended for this had their magnetic permeability determined, and no part used in the construction has a permeability differing from unity by more than 0·001 per cent.

The balance was examined for stability and sensitiveness at Messrs.

Oertling's works with satisfactory results; a difference of one-tenth of a milligramme may be detected.

2. *The marble cylinders and fittings.*—Insulation and permeability tests were made on various samples of marble early in the year; eventually First Statuary Carrara Marble was chosen as most suitable for the work. An experimental marble cylinder was wound with a double helix and the insulation satisfactorily carried out; the results of the tests leave little doubt as to the advantages of the double helix. The winding of both suspended cylinders has now been completed, and it is anticipated that the fixed cylinders will be finished in September. The linear measurements and insulation tests have yet to be made. Unless unforeseen difficulties arise the balance equipment should be completed, and the whole ready for preliminary observations by the end of the year.

During the early part of the year Mr. F. E. Smith completed his researches into the construction of a mercury unit of resistance, of which some account was given in the last report. The results have been communicated to the Royal Society and are being published in the 'Philosophical Transactions.' The values of the various tubes (eleven in number) are very accordant, and a mercury standard of resistance of a high degree of accuracy now exists. Since the completion of his work the specification of the Clark cell has engaged Mr. Smith's attention, and a detailed account of his work forms an Appendix to the present Report. Mr. Smith has amply confirmed the result of previous investigators that the greater part of the difficulty in obtaining entirely concordant results for the various cells set up by different experimenters is due to the mercurous sulphate. He describes three methods of preparing the paste which lead to identical results, and which have the advantage that cells set up with these pastes have, the same E.M.F. within one or two hundred thousandths of a volt immediately after manufacture. In the first method due to Professor Divers and Mr. Shimidzu the paste is prepared by the action of fuming sulphuric acid on mercury; in the second, following Professor Carhart, it is prepared by the electrolysis of weak sulphuric acid and mercury; while in the third mercurous sulphate is dissolved over a water bath in sulphuric acid. The acid solution is then poured into a large volume of distilled water and the mercurous sulphate is precipitated in a pure form. In all cases it is important that, as advised by Mr. Swinburne and Professor Carhart, the salt should be washed, for a Clark cell, with zinc sulphate, and for a cadmium cell with cadmium sulphate, and not with distilled water. Mr. Smith is continuing his inquiries and hopes shortly to be able to issue a complete specification for Clark and cadmium cells. The completion of the Ampère Balance will enable an absolute determination of their E.M.F. to be made.

The Committee regret to report that no further progress has been made since their last report with the experiments to determine the permanence and reliability of the platinum resistance thermometers described in that report.

It was pointed out last year that a special resistance box was required to enable the work to continue; unfortunately the funds necessary for its purchase were not forthcoming, and the work has remained stationary for a year.

The Committee would consider it most unfortunate if work of a very real importance, on which a start has already been made and

considerable funds expended in the purchase and investigation of pure platinum wire, should lapse for want of support, and they trust that their recommendation in favour of the continuance of the work may this year be accepted.

Meanwhile they would call attention to the very complete comparison up to a temperature of 1000° C. between the constant volume nitrogen thermometer, the platinum resistance thermometer, and the platinum—platinum-rhodium thermo couple communicated recently from the National Physical Laboratory to the Royal Society by Dr. Harker.

The Committee have received a cordial invitation to co-operate in the Electrical Conference at St. Louis during the forthcoming autumn, and have asked Professor Perry and the Secretary, who are attending as delegates of the Institution of Electrical Engineers, to represent their views on two questions of special interest.

The first of these relates to a proposal by Professor Carhart to substitute the saturated cadmium or Weston cell for the Clark cell as a recognised standard of E.M.F. The Committee are aware that the fact that the temperature coefficient of the cadmium cell is one-twentieth of that of the Clark cell offers many valuable advantages, but in view of the fact that experiments designed to lead up to a satisfactory specification of the cell are in progress at the National Physical Laboratory, and that the completion of the Ampère balance would enable the absolute E.M.F. of the cell to be determined, the following resolution was passed at the last meeting :—

'The Committee are not prepared at present to displace the Clark cell, and prefer to wait for the conclusion of the experiments at the National Physical Laboratory, and with the new balance, before coming to a decision as to the value to be assigned to the E.M.F. of the saturated cadmium cell.'

The second question relates to certain proposals as to nomenclature which are to be brought forward by Dr. Kenelley. These are : (A) that a systematic nomenclature should be agreed upon for magnetic units, and (B) that the prefix 'Abs' should be used to indicate that a unit is given in the absolute C.G.S. electro-magnetic system, and 'Abstat' to indicate that the unit in question is in the absolute C.G.S. electrostatic system.

Thus an Abs volt would be the C.G.S. electro-magnetic unit of E.M.F. and 'Abstat' volt the C.G.S. electrostatic unit of E.M.F.

These proposals have been discussed by the Committee, which have agreed to the following resolution :—

'With regard to the choice of magnetic units the Committee are of opinion that the only two systems which need to be considered are the C.G.S. system and the Ampère-Volt-Ohm system, and that the quantities to be named, if any, are—

(1) Magnetic Potential.
(2) Magnetic Flux.[1]
(3) Magnetic Reluctance.

Of the above two alternatives the Committee are in favour of the C.G.S.

[1] The name 'Maxwell' was recommended by the Paris Congress, 1900, as the name of this unit, and this recommendation was adopted by the Committee at Bradford.

system as that on which to base any nomenclature of magnetic units, but are of opinion that a system of nomenclature is not called for.'

The Committee disagree with Dr. Kenelley's prefixes for the absolute electro-magnetic and absolute electrostatic systems of units, and express the opinion that no system of prefixes should be employed in which each prefix does not bear some definite numerical signification.

In view of the work still necessary with regard to the Ampère balance, the cadmium cell, and the platinum standard of temperature, the Committee recommend that they be reappointed, with a grant of 50*l.*, that Lord Rayleigh be Chairman, and Dr. R. T. Glazebrook Secretary.

APPENDIX I.

On Anomalies of Standard Cells. *By* F. E. Smith.

From the National Physical Laboratory.

During the past two years certain anomalies of Clark and of cadmium cells have been under investigation at the National Physical Laboratory. The work is still far from completion, but the essential results so far obtained are given in this paper.

In March 1902 some experiments at Bushy House resulted in the isolation of the depolariser employed in both standards as the great disturbing element. Lord Rayleigh, in his paper in the 'Phil. Trans.' for 1885, § 44, had shown this to be the case, and Mr. Swinburne arrived at the same conclusion in 1891,[1] while recently in America Professor H. S. Carhart and Mr. G. A. Hulett have traced the variations in E.M.F. of the cadmium cell to the same source. A new specification of the mode of manufacture of the paste was thought to be desirable, and this problem was the first to receive attention.

In order to be independent of the variations of the other elements, cells were constructed of a type indicated by the arrangement

$$\underset{}{\text{Hg}} - \underset{(a)}{\text{Paste}} - \text{Solution and Crystals} - \underset{(b)}{\text{Paste}} - \text{Hg}.$$

where *a* and *b* represent pastes made with different samples of mercurous sulphate. The Rayleigh H form of vessel was employed. Preliminary observations showed that when the same paste occupied the two limbs, such a cell had no measurable E.M.F.

In addition a cell typified by the arrangement

Amalgam
|
Hg — Paste (A) — Solution and Crystals — Paste (C) — Hg
|
Paste (B)
|
Hg

was largely employed, a four-limb vessel, similar to two Rayleigh H form of vessels crossed, being used to set up the standard. In this case there

[1] See *B.A. Report*, Cardiff, 1891.

is one negative pole and three positive ones, and the E.M.F. between any two of them may be measured. Such a cell not only indicates whether a particular paste is abnormal or not, but each of the three groups of elements may be compared with an external standard. It is possible, of course, that a change resulting in one of the pastes may affect the neutrality of the solution, and so the E.M.F. of all three groups. All observations were made in a constant temperature room, the cells being immersed in paraffin oil.

The earlier results of the investigation are omitted, but the differences in E.M.F. due to pastes made from purchased samples of mercurous sulphate are shown by measurements made of cell No. 1 (4 limbs) and cell No. 28 (2 limbs), the observations covering a period of rather more than two years. The pastes have been distinguished by the letters K, H, and R; all were subjected to the same treatment and advantage taken of the latest methods for their preparation known at that time.

TABLE I.

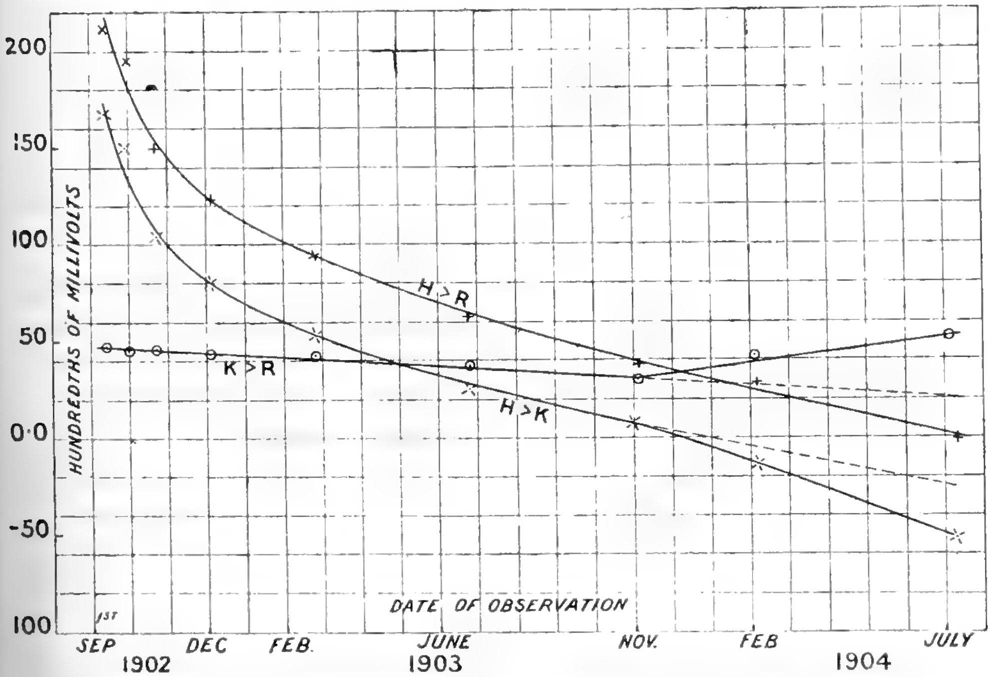
Date of Observation.	Clark Cell, No. 1 (4 limbs).			Clark Cell, No. 28 (2 limbs).
	H>R.	K>R.	H>K.	H>K.
Sept. 8, 1902 .	+0·00213	+0·00047	+0·00166	+0·00168
Sept. 30, „ .	195	45	150	104
Oct. 23, „ .	150	46	104	79
Dec. 2, „ .	123	43	80	59
Feb. 24, 1903 .	94	42	52	No obs.
June 24, „ .	62	37	25	− 5
Nov. 2, „ .	37	30	7	−32
Feb. 6, 1904 .	27	41	−0·00014	−50
July 9, „ .	−0·00001	51	− 52	−70

It is clear that although the effect of each paste is not known two of them have certainly changed, of which one is K. In the chart curve H R shows the change in E.M.F. of the H group, assuming the R group to remain constant; similarly the H K curve represents the change in voltage of this group, K being assumed constant, and like remarks apply to the third curve. There is a sudden break in the directions of the curves H K and K R shown after the observations of November 2, while none is shown in H R; the deflections consequently indicate that the element K must have changed in an abnormal fashion. Indeed between November 2, 1903, and July 9, 1904, the E.M.F. of the K group apparently increased by at least 0·0003 volt; a rise of exceptional magnitude. A fall in voltage is the usual feature.

The fact that the E.M.F. of a cell had changed by as much as 0·16 per cent. was very disconcerting. It is true that a difference between H and R was anticipated, for H was a pale yellow colour, while R was grey. On the other hand the paste K was also slightly yellow, yet no such difference is observed between K and R. It was thought that the mode of manufacture of the sulphate might influence the properties of the product. Mercurous sulphate is often prepared by precipitation, either $Hg_2(NO_3)_2$ and Na_2SO_4 or $Hg_2(NO_3)_2$ and H_2SO_4 being employed; traces of the resulting nitrate in the final product would certainly introduce a disturbing element. Again mercurous nitrate is often associated

with a basic nitrate, and basic salts are to be avoided, as will afterwards be seen. Samples of the salts were prepared by these precipitation methods and the results were far from satisfactory. Two samples of the sulphate were also obtained from the same manufacturer; the Clark cells prepared with these differed in E.M.F. by 0·0004 volt; each was subjected to the same treatment and there was no observable difference in colour.

A more satisfactory specification of the depolariser being desirable, other modes of manufacture eliminating the above troublesome elements were sought. Concentrated sulphuric acid and mercury react very slowly at ordinary temperatures, but much more rapidly at temperatures approximating to 300° C. The resulting salt is associated with H_2SO_4, which probably is not very difficult to remove if the salt be in a fine state of division. Dr. Muirhead has prepared mercurous sulphate in this way and forwarded two Clark cells containing the product to Bushy House. A



second method of preparation due to Divers and Shimidzu is reported in the 'Journal of the Chemical Society' (**47**, 639). Briefly, pure mercury and fuming sulphuric acid saturated with SO_3 are brought into contact. They react in the cold, though there is no visible evidence for some time owing to the solubility of the product in the liquid; the acid also becomes saturated with SO_2. If the main portion of the liquid be removed from the salt, this latter may be freed from SO_2 by warming; mercurous sulphate associated with H_2SO_4 is thus obtained. The acid is removed by washing. Dr. Carpenter has prepared five samples of the salt in this way; they were made from five lots of the fuming acid from different manufacturers and mercury distilled *in vacuo* at the laboratory. These sulphates were examined in four-limb cells of the cadmium type; the results of the observations are given in Table II. The standard of reference is cell No. W 17, a cadmium cell more than two years old and known to have changed but little since its manufacture.

TABLE II.—*E.M.F. of Cadmium Cells minus E.M.F. of W 17. Differences in hundredths of a millivolt.*

Date of Observation	Cell No. 52			Cell No. 53			Cell No. 54		
	a.	*b.*	*c.*	*a.*	*b.*	*c.*	*a.*	*b.*	*c.*
April 4, 1904	+38	−21	−19	+38	−14	−13	+38	+14	−18
April 18, „	+35	−30	−20	+39	−13	−14	+35	+13	−18
May 3, „	+30	−43	−20	+32	−14	−14	+34	+12	−19
June 13, „	+27	−50	−21	+32	−14	−14	+34	+10	−19
July 9, „	+23	−54	−21	+30	−14	−15	+34	+10	−20

The pastes 52*a*, 53*a*, 54*a* were prepared with the same sample of Hg_2SO_4; it was purchased and prepared in a similar manner to the sulphates dealt with in Table I. 54*b* was also a purchased sulphate. The remaining specimens were prepared by Divers' method.

It will be observed that all the pastes change so as to reduce the E.M.F. of the cell; but whereas the E.M.F. of the cells prepared with purchased sulphates is greater than that of W 17, those made up with the Nordhausen sulphates have in each case lower E.M.F.s. Cell No. 52*b* is exceptional in the fall of its voltage. The difference in the prepared pastes, though small, condemns part of the method of preparation, and further investigation became necessary.

The method of preparation adopted by Dr. Carpenter was at first repeated. Close observation showed that on formation the sulphate cakes considerably, and is accompanied at the surface of contact with the mercury by a compound of a light brick-red colour. If without freeing from the acid or SO_2 the product is added to distilled water, reduction of part of the sulphate apparently occurs, mercury is precipitated as a black powder, and the red compound entirely disappears. (The mercury thus precipitated is a valuable addition to the paste, the conversion of mercuric sulphate to the mercurous condition being rendered possible by its presence.) The salt produced by freeing the first product from SO_2 also loses the brick-red tint, and is finally obtained as a pure white paste. On prolonged washing with water, however, hydrolysis results and the colour changes to pale yellow. Two samples of hydrolysed mercurous sulphate were thus prepared, the one being washed for one hour with water and the other for twenty-four hours. An experimental cell indicated that the more hydrolysed product if employed to set up a cadmium cell would cause the E.M.F. of that cell to be greater by 0·00064 volt than if prepared with the first sample. The presence of this hydrolysed product is therefore to be avoided, and washing by water prohibited.

About this time, through the kindness of Professor Ayrton, the results of some experiments by Professor H. S. Carhart and Mr. G. A. Hulett, of the University of Michigan, were communicated to the Laboratory. Professor Carhart has also sought a standard method of preparing the depolariser, and suggests that any prepared sulphate be washed with cadmium sulphate (or zinc sulphate for Clark cells) in order to prevent hydrolysis. Prior to this, Mr. Swinburne, in a letter to Dr. Glazebrook, suggested the precipitation of the sulphate intended for Clark cells from saturated solutions of mercurous nitrate and zinc sulphate, the washing to be effected with alcohol or saturated zinc sulphate solution.

Omitting the description of further experiments, the final mode of preparing the mercurous sulphate for standard cells is here given.

Fuming sulphuric acid saturated with SO_3 (32 per cent. of SO_3 is a convenient specification) is added to sufficient pure distilled mercury to ensure the latter being always in excess. The mercury should be contained in a clean glass vessel and violently agitated by a glass stirrer, so that the product may be in a fine state of division. After seven or eight hours the reaction will be sufficiently advanced for the sulphate to be separated from the acid, but if convenient the action may go on for some days. Carefully pour off as much of the strong acid as possible into a large volume of water or into an empty vessel, and afterwards add the pasty product left to thirty or forty times its bulk of distilled water. Mercury is precipitated and a considerable quantity of heat is evolved owing to the dilution of the acid. A few minutes suffice for the sulphate to settle, when the acid liquid may be decanted and the salt well washed by agitation with acidulated water (1 part of conc. H_2SO_4 to 10,000 parts of distilled water). Filtering follows, a filter pump being employed to effect exhaustion. It is advisable next to pound the damp sulphate thoroughly in an agate mortar to ensure the absence of small caked masses, after which acidulated water is again added, filtering effected, and the salt washed on the filter-paper with two or three lots of neutral saturated cadmium sulphate solution (or zinc sulphate solution for Clark cells). The salt is now removed to a small flask, saturated cadmium sulphate solution added, and the whole well shaken and then allowed to stand for twenty-four hours. Filtering follows, then three more washings with cadmium sulphate solution, removal to a flask once more with $CdSO_4$ solution, and at the end of twenty-four hours the solution should still be neutral to Congo red. If so, the sulphate may be filtered and is ready for the manufacture of the paste. The whole of the operations should be conducted in a room screened from sunlight. As thus prepared the mixture of mercurous sulphate and mercury is of a dark grey colour. Cells set up with paste prepared from it require no ageing, and the constancy obtained with pastes made from materials obtained from different sources is an indication of the purity of the salt.

Table III. gives the results of comparisons between cadmium cells set up with pastes prepared in this way and cadmium cell W 17. The latter in every case has the greater E.M.F. Differences are expressed ir hundredths of a millivolt.

TABLE III.

Date of Observation	Cell No. 66			Cell No. 67			Cell No. 68		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
May 12, 1904	−24	−26	−24		—			—	
,, 12, ,,	−21	-20_5	−22		—			—	
,, 12, ,,	-20_5	-20_5	−21		—			—	
,, 16, ,,		—		−27	−25	−28		—	
,, 16, ,,		—		−22	−21	−21		—	
,, 16, ,,	−21	−20	−20	−21	−21	−20		—	
June 13, ,,		—			—		−29	−29	−27
,, 13, ,,		—			—		−23	−22	−23
,, 13, ,,	−21	-20_5	−21	−20	-20_5	−19	−21	−20	−19
July 6, ,,	−21	−21	−20	-19_5	−20	-19_5	−20	−21	−20
,, 9, ,,	-20_5	-20_5	−20	−20	−21	−20	−20	-20_5	-19_5

The first set of observations with each cell was made about five minutes after adding the solution; the second set of observations about twenty minutes afterwards; and the third set three hours afterwards. For the first two sets of observations the temperature of the four-limb cells was unsteady; for the remaining observations they and W 17 were at the same steady temperature. Other cells of the Rayleigh H form have been constructed, and the comparisons are equally satisfactory.

An alternative method of preparing the salt was next sought. This second method is very simple. Any purchased sample of mercurous sulphate is heated together with mercury and concentrated H_2SO_4 on a water-bath for half an hour, the mixture being stirred occasionally. At the end of that time the remaining solid is allowed to settle and the hot clear acid carefully poured into a large volume of distilled water. Mercurous sulphate is soluble to a considerable extent in hot concentrated H_2SO_4; the result of the dilution is, in consequence, to precipitate the salt. As thus produced the mercurous sulphate is in a finely divided state and of a pure white colour. It is well to at once admix with a little mercury and filter. The washing is performed as before. Portions of three purchased samples of Hg_2SO_4 were dealt with in this way, and after treatment gave identical results with the cells dealt with in Table III. The three original samples prepared in the ordinary way produced cells differing in E.M.F. from the standard by 40, 160, and 10 hundredths of a millivolt.

A third method devised by Professor Carhart does not necessitate the use of concentrated acid. In order to hasten the reaction between mercury and dilute sulphuric acid (one to six) an electric current is passed from the mercury to a sheet of platinum foil suspended in the liquid. It is essential that the liquid be kept well stirred so as to keep the mercury surface exposed. Professor Carhart has employed a beaker or crystallising dish to contain the liquids, and used a current of about 0·3 ampère; the current density, however, is not stated. At Bushy House the salt so produced has been compared with those prepared by the two previous methods. Under ordinary circumstances about three grams of the salt—very grey owing to the presence of mercury in a fine state of division—is obtained per hour. The current density at Bushy House has been about ·01 ampère. It was gratifying to find that the product (washed as before) gave identical results with the other methods. Very violent agitation was maintained during the preparation. When the liquid is not stirred a yellow compound (apparently turpeth mineral $HgSO_4.2HgO$) is also produced, and cells the pastes of which are prepared with the product have an E.M.F. when first set up more than a millivolt higher than the normal. Particular stress must therefore be laid on the instruction to keep the mercury surface well exposed. The same thing was found to happen when attempting to form mercurous sulphate by the electrolysis of a saturated cadmium sulphate solution in an H-form vessel, the electrodes being pure mercury.

It will be observed that the remarks on the depolariser apply equally to Clark and to cadmium cells. Cadmium cells alone were made up in the final tests because of their small temperature coefficients; but Clark cells have also been set up and similar results obtained. It is also necessary to add that all purchased samples of Hg_2SO_4 are not so abnormal as those dealt with in Table I., nor does the E.M.F. of an abnormal cell always fall so rapidly as is indicated there. (The rate of fall is probably

a function of the fineness of the sulphate.) Evidence of remarkably stable cells set up with purchased mercurous sulphate is afforded by six cadmium cells made at Bushy House in April 1902 : these have been in constant use, and in the case of two of them have frequently been short-circuited through 100 ohms. One of these cells is taken as a standard in the comparisons. By reference to a seventh cell made up in June 1904 with a paste made from sulphate identical with that employed for the previous ones it is thought probable that the whole six cells have fallen ·07 millivolt since their manufacture. Table IV. gives the result of the comparisons.

TABLE IV.

Date of Observation	16>17	16>18	16>19	16>20	16>21
May 5, 1902 . .	·00000	·00000	·00000	·00000	·00000
Sep. 12, „ . .	0	+ 1	0	+ 1	0
Feb. 25, 1903 . .	0	0	0	0	0
Dec. 14, „ . .	+ 0_5	− 0_5	0	0	+ 0_5
Feb. 6, 1904 . .	0	0	0	0	0
July 9, „ . .	+ 0_5	+ 0_5	− 1_5	− 0_5	0

At the present time the E.M.F. of a cadmium cell set up with a paste made from fuming sulphuric acid and mercury is less than that of these cells by 0·21 millivolt.

With respect to the other elements of standard cells it is proposed to investigate the cadmium and zinc amalgams, and the solutions of the sulphates of these metals, in a manner very similar to that employed for the pastes. Much valuable information has fortunately accumulated respecting the influence of impurities in these, so that probably the task is a light one. It is interesting to note that neither of the amalgams should have its surface exposed to the atmosphere for any length of time ; it is preferably covered with water or a solution of the sulphate of the metal. This prevents oxidation. In addition to these investigations the effects of acidity and basicity are to be determined, together with observations in connection with lag, polarisation, temperature coefficients, &c.

Remarks on the Rayleigh H Form and the Board of Trade Tube Form of Standard Cells.

In 1892 Dr. Kahle, in a paper read before the British Association at Edinburgh, described some researches made by him on the Clark cell. Comparisons of H cells set up by him with tube cells set up by Dr. Glazebrook at Cambridge led to the assignment of an E.M.F. to the H cell, four ten-thousandths of a volt less than that of the Board of Trade form. This difference in value has been often quoted, and is at the present time accepted as a fact. In view of the discrepancies produced by the paste, together with theoretical considerations, it was thought desirable to investigate this difference if such should exist. For this purpose the H and tube forms of cell were combined. In addition to the usual terminals to the H cell, a zinc rod was inserted in the limb containing the paste, so that the arrangement of the elements in this limb was in accordance with the specification of the Board of Trade pattern. The sole difference in the elements of the H and tube cells was therefore the substitution of the zinc rod for zinc amalgam. In some cases the zinc rod

was amalgamated, in others it was merely cleaned, in no case did it touch the paste. With two cadmium cells set up similarly, a rod of cadmium amalgam contained in a glass tube perforated at a few points replaced the plain cadmium rod. Very steady temperatures were maintained before taking observations.

Table V. gives the results of comparisons of these Clark and cadmium cells. The standard adopted for the Clarks was cell No. 10, a standard more than two years old and fairly constant; that for the cadmium cells was a third cell, No. 48, made up at the same time.

Cells numbered E 10 and E 11 contained a different paste from that in C 3, C 7, C 9. The differences between H and T are small and irregular, and probably explained by the non-uniformity of the surface of the zinc rods and slight differences in the concentration of the solution. The zinc rods in E 10, E 11, C 3, and C 7 were amalgamated; that in C 9 was cleaned only.

TABLE V.—*Differences in Hundredths of a Millivolt.*

Date of Observation	Clark Cells										Cadmium Cells			
	E 10		E 11		C 3		C 7		C 9		49		47	
	H.	T.	H.	T.	H.	T.	H.	T.	H.	T.	H.	T.	H.	T.
July 5, '04	−2	−8	+0	+0	−1	−7	+10	−2	...		+2	+2	+0	+1
" 6, "	+0	+2	+3	−5	+4	+0	+10	+7	...		+2	+3	+2	+1
" 7, "	...		...		+6	+2	+7	−2	+10	+2	...		...	
" 8, "	...		...		+5	+1	+9	+2	+8	+15	...		...	
" 9, "	+4	−6	+2	+0	+6	+2	+8	+12	+7	+3	+2	+2	+2	+1
Means	+1	−4	+2	−2	+4	-0_4	+9	+3	+8	+7	+2	+2	+1	+1

The observations show that no such difference as 0·0004 volt exists between the two forms; the difference found in 1892 is to be attributed to other causes, probably the pastes employed.

APPENDIX II.

On the Electromotive Force of a Clark Cell. By A. P. TROTTER.

A determination of the electromotive force of the Clark cell (Wolff's large pattern) in terms of the ampère and ohm, has been made recently at the Board of Trade Electrical Standards Laboratory. The ampère, as measured by the Standard Ampère Balance of the Board of Trade, was passed with suitable precautions through a manganin coil having a resistance of $1{\cdot}4343_6$ ohm at 15°·0 C., and the difference of potential between the ends of this coil was compared with that of the Clark cell upon a low-resistance potentiometer. After necessary corrections the electromotive force of the Clark cell was found to be 1·4329 volts at 15°·0 C. The temperature of the Clark cell was read by a thermometer in an oil bath in which the cell was placed, estimating to 0°·01 C. The cell had been kept for several months in a constant-temperature room and had not varied in temperature by more than 0°·05 C. for forty-eight hours before the comparisons.

Seismological Investigations.—Ninth Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. J. MILNE (*Secretary*), Lord KELVIN, Professor T. G. BONNEY, Mr. C. V. BOYS, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Dr. R. T. GLAZEBROOK, Mr. M. H. GRAY, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. NELSON RICHARDSON, *and* Professor H. H. TURNER. (*Drawn up by the Secretary.*)

[PLATES I. AND II.]

CONTENTS.

I. *General Notes on Stations and Registers.*

DURING the past year the registers issued are Circulars Nos. 8 and 9. These refer to Shide, Kew, Bidston, Edinburgh, Paisley, Toronto, Victoria, B.C.; Baltimore, San Fernando, Cairo, Ponta Delgada, Cape of Good Hope, Alipore, Bombay, Kodaikanal, Batavia, Irkutsk, Perth, Mauritius, Trinidad, Tiflis, Christchurch, Wellington, Cordova, and Tokyo. Captain H. G. Lyons, R.E., Director-General of the Survey Department at Cairo, writes that the Abbassia records terminated on December 23, 1903. On the same day they were recommenced at Helwan, long. E. 31° 21′, lat. 29° 52′. At Abbassia, in the delta, the foundations were on sand, and during wet weather may have been disturbed. At Helwan the instrument stands on a limestone pier founded on solid rock.

It is anticipated that an instrument will shortly be installed at Malta.

The multiplication in the number of stations, scattered as they are all over the globe, has led to a great increase in the work of correspondence and reduction which has to be undertaken at Shide. Much of this work might well be done by an assistant under the supervision of the Secretary, leaving the latter more free to devote himself to scientific problems. The Committee consider that the time has arrived when a fund should be established to provide a sufficient income for securing the continuity of the work in the future. Upon such a fund the salary of an assistant would be a principal charge. The Committee are happy to be able to report that Mr. M. H. Gray has very generously given the sum of 1,000*l.* to serve as the nucleus of such a fund, while the Committee on Geophysics of the Carnegie Institution of Washington have also expressed a desire to contribute to the important work which is being carried on at Shide. The Committee are in correspondence with the Executive Committee of the Carnegie Institution, and they trust that donors will come forward to assist in putting the work upon a permanent basis.

It may here be mentioned that Mr. M. H. Gray has already given

material support to the station of Shide; his brother, Mr. R. K. Gray, provided the instrument for San Fernando; Mr. Joseph Wharton, of Philadelphia, U.S.A., gave the instrument installed at Strathmore College, near that city; pendulum apparatus was given to Shide by Mr. A. F. Yarrow; the instruments in Hawaii, Victoria, and Mauritius were paid for, or partially paid for, by funds put at the disposal of your Secretary; while the remaining installations were established by institutions or Governments in the countries where they are now working.

II. *On the Comparison of Records from three Milne Horizontal Pendulums at Shide.*

These pendulums and their installations referred to in the following note are described in the British Association Reports, 1902, p. 60, and 1903, p. 81.

Pendulum A is the type instrument, and carries a load of 243 gms. It stands on its own pier, records E.W. motion, and its period, like similar instruments in other parts of the world, has been kept at about seventeen seconds.

Pendulums B and C stand on the same pier and swing on the same cast-iron upright. B is parallel to A, and, like it, records E.W. motion. C responds to N.S. motion, but by means of an arm attached to it, similar to the arrangement shown in the British Association Reports for 1902, p. 61, fig. 1, its records are made side by side with those of B. At intervals of several months the loads carried by B and C have been purposely varied, and the object of this note is to show the differences in the results obtained in consequence of such changes. In considering these differences two points not to be overlooked are, first, that only the movements of A and B are comparable; and secondly, that the swinging of B might cause motion in C, and *vice versa*.

The comparisons given in the following table refer to the number of records given during different periods by A, B, and C, and the number of

—	Number of Records			Number of Early Commencements		
December 28, 1902, to April 28, 1903	A	B	C	A	B	C
I. A, p. 17, W. 243 grms.						
I. B, p. 17, W. 237 "	35	35	31	15	12	15
I. C, p. 20, W. 155 "						
April 28 to December 6, 1903						
II. A, p. 17, W. 243 grms.						
II. B, p. 17, W. 237 "	29	40	50	9	12	47
II. C, p. 20, W. 404 "						
December 8, 1903, to May 2, 1904						
III. A, p. 17, W. 243 grms. "	22	40	31	8	33	27
III. B, p. 30, W. 394 "						
III. C, p. 20, W. 404 "						

times each of these pendulums commenced to record either sooner than the others or at least simultaneously with one of the others. P=period in seconds, and W=load carried by the booms expressed in grammes.

During the first period the records accord fairly well with what might be expected, the small moment of C accounting for the small number of its records.

In the second period, when the load on C was increased threefold, we find that it gives the largest number of records and the largest number of early commencements. The large increase in the records on B may be due to the influence of C swinging on the same support. In the last period, when B carried a load practically equal to that on C, and had its time of swing increased to thirty seconds, we see that it gave the greatest number of records and also most frequently was disturbed before the others.

Although these records are not strictly comparable, and for the most part only refer to mere thickenings of the photographic trace, they suggest that an increase in load and of period in the type instruments would result in increased sensibility.

III. *Improved Record Receiver for Horizontal Pendulum Seismograph.*

The accompanying illustrations, figs. 1 and 2, show two views of a new seismograph recorder.

The instrument consists of a light brass cylinder, D, 1 metre in circumference and 160 millimetres wide, mounted upon a steel spindle. One of the projecting ends of this spindle has a deep-threaded helix of 6 millimetres pitch cut in it; this being suitably mounted upon roller bearings, advances the cylinder 6 millimetres for one turn in four hours, by a gear connection with a clock. The bromide paper carried on the cylinder is changed every 3·5 or 4 days.

A cylindrical mirror has been introduced to give a greater concentration of the light on to the boom-plate.

For the time record mark upon the bromide paper a shutter actuated by an electro-magnet is employed, the light being shut off from seven to ten seconds every hour. For this purpose a regulating clock with suitable electric contacts is required. An example of records from the new and old form of receiver is shown in Plate I.

The advantages of the new arrangement are :—

1. Although the paper moves beneath the end of the boom at more than four times the rate (250 millimetres per hour) that it does in the original receiver, only one-half the quantity of paper is used. This implies a large reduction in expense for paper and developer, the latter being applied by a brush.
2. An open diagram is obtained on which wave-periods can be measured.
3. Movements of small amplitude are easily recognised.
4. Records can be quickly inspected and are easily stored.

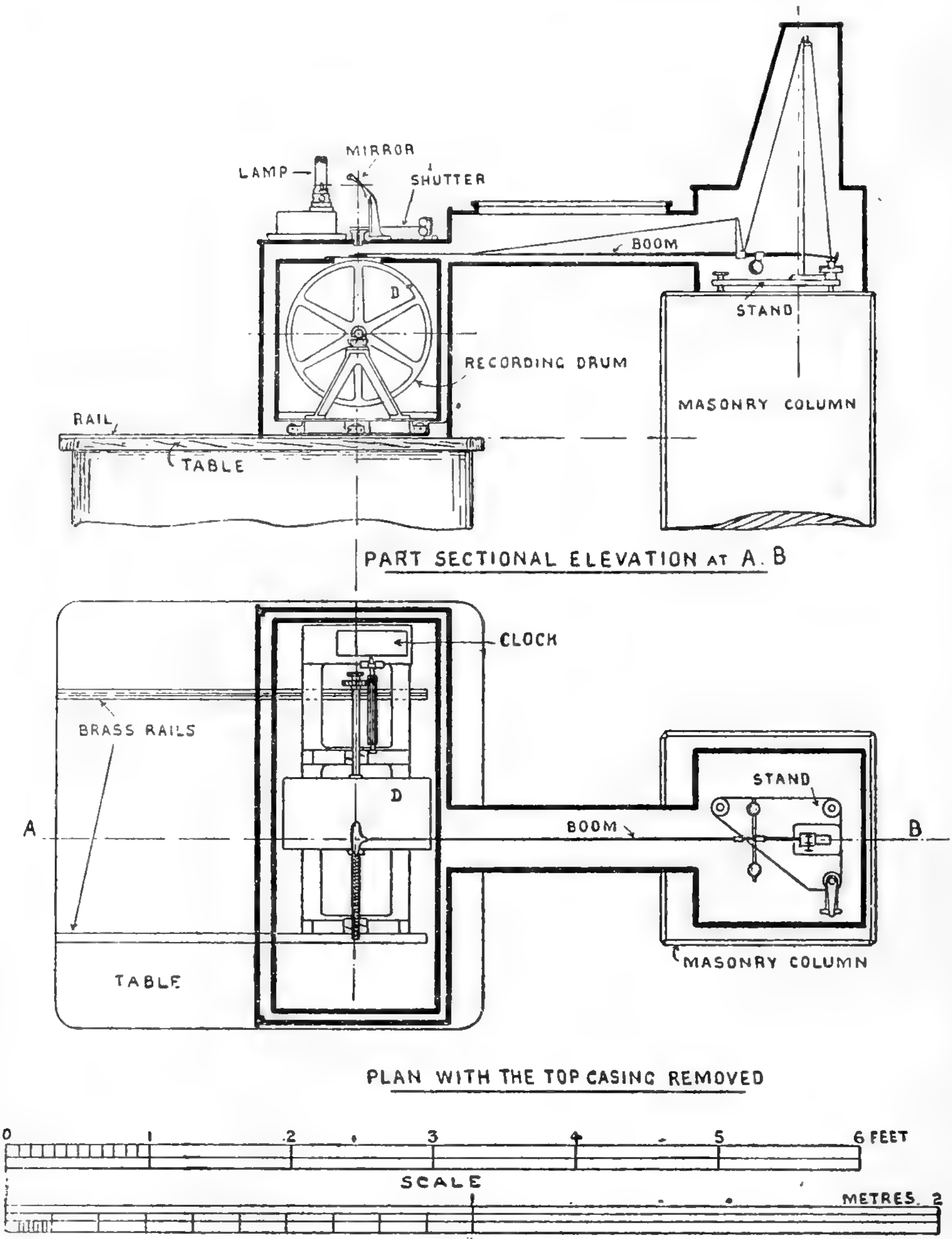
IV. *The Origins of Large Earthquakes recorded in* 1903 *and since* 1899.

The origins of the large earthquakes recorded in 1903 are indicated by this Shide register number upon the accompanying map, Plate II. In the registers (Circulars 8 and 9) there are 135 entries for this year, whilst on the map only sixty-four origins are indicated, which means that there were about seventy-one earthquakes the materials relating to which were insufficient to enable their origins to be determined. Even with the origins which have been determined, the notes of interrogation attached to

numbers on the map indicate that such determinations are accompanied by uncertainty.

Speaking generally, it may be inferred that about 50 per cent. of the

FIGS. 1 AND 2. Milne's Horizontal Pendulum (seismograph) with new recording arrangement.



large earthquakes have disturbed the world's surface as a whole, whilst the remainder have only affected areas equal to those of single continents.

The greatest activity is again along the Libbey Circle (radius 70° and centre 180° E. or W. long., and 60° N. lat.). Marked activity has taken place at the junction of regions E. and F., and in the eastern por-

tion of the E., both of which may be described as regions in which there are intersections of tectonic folds.

Maps corresponding to the one here given can be found in the British Association Reports for 1900, 1902, and 1903.

V. *On International Co-operation for Seismological Research.*

In 1902 the British Government received an official invitation from Germany to take part in a Conference the object of which was to establish an international inquiry about earthquakes. Acting under the advice of a Committee appointed by the Royal Society, the Board of Education appointed Professors G. H. Darwin and J. Milne to represent Great Britain at the proposed Congress, which took place in Strassburg July 23 to 28, 1903. Twenty-five States or countries were represented, but the total number of delegates and guests who were at liberty to take part in the proceedings was 100, out of which sixty-two were Germans. Final results were arrived at by single voices, each country having one vote; thus Great Britain and her colonies, like the German Empire, had each one vote only. France was not officially represented.

The more important results arrived at were as follows :—

A Central Association is to be formed with its headquarters in Strassburg. Each contributing country will be represented by one member of a governing Committee, which elects a President, a Chief for the Central Office, and a General Secretary. The Chief will reside in Strassburg, but it was decided that the President and Secretary should be elected from outside Germany.

The work of the Association would be as follows :—

1. To carry out observations after a common plan.
2. To carry out experiments on important matters.
3. To establish and support observatories.
4. To collect, study, and publish reports or *résumés* of the same.

The cost of this work, including a Secretary's salary, is to be for the first twelve years about 1,000*l*. per annum, twelve years being the duration of the Convention. The contributions to make up this sum are to be apportioned amongst the co-operating States according to their population, the British contribution to be 160*l*. per year. Should Great Britain join the Convention, as it will be necessary to send a representative to the Governing Committee, the total annual outlay will be about 200*l*.

Whilst at Strassburg the British delegates explained that they were in no way empowered to pledge his Majesty's Government, and that they had been informed that their Government would not take action that had not the support of the International Association of Academics. At the last meeting of this Association, held in London May 24 to 30, 1904, the advisability of international co-operation for purposes of seismological research was discussed, with the result that it has been referred for further consideration to the following Committee: Professors A. Schuster (Chairman), Helmert, de Lapparent, Mojsisovics, Agamennone, Karpinski, and T. C. Mendenhall.

The Foreign Office and the Board of Education have been informed of this action.

On April 21, 1904, the Seismological Committee of the Royal Society reported to the Council of that body as follows :—

(1) That this Committee is of opinion that any moderate subsidy likely to be available would be most profitably expended in supporting the seismological work inaugurated by the British Association, and that there is urgent need of such help, which should be a first call on any such funds.

(2) Assuming this need supplied, the Committee would approve the further co-ordination of the work by joining the proposed Association.

VI. *Notes upon Seismological Work in various Countries.*

1. *Austria.*

With the object of recording earthquakes with a local origin, Austria is divided into sixteen districts, each with many observers. Their notes, which are for the most part made without the aid of special instruments, are collected at a local centre. From 120 to 200 disturbances are noted annually, and the registers are published separately or collectively by the K. Akademie der Wissenschaften in Wien.

At Trieste, Laibach, Kremsmunster, Lemberg, and Pribram there are instruments to record earthquakes with a distant origin. Four of these stations have received State subventions. The registers are published in series with the above.

An important publication issued by Dr. A. Belar, of Laibach, is 'Die Erdbebenwarte.' In it we find articles relating to seismological investigations, notes relating to such work in general, and a catalogue of the Laibach observations.

2. *Belgium.*

Station Géophysique d'Uccle. Registers relating to earthquakes with distant origins are published every three months.

3. *Germany.*

Strassburg issues a monthly register of earthquakes with distant origins with corresponding notes from a few foreign stations, together with a list of a few earthquakes which have been felt in various parts of the world. It is supported by the State.

Hamburg issues a list similar to that issued by Strassburg, but more complete. The station was started as a private enterprise by Dr. R. Schütt, but its founder has presented the same to the city authorities.

Göttingen issues a register relating to the observations made at the University.

Teleseismic observations are also made at Jena and Potsdam. It is proposed to establish thirty-four more stations within the German Empire.

4. *Great Britain.*

A Committee of the British Association enjoys the co-operation of thirty-nine stations, which are fairly evenly distributed over the world. Each station is provided with similar apparatus intended for a particular class of teleseismic observation. The registers from these stations are published every six months, to which is added once a year a short report. These publications are distributed to the co-operating stations and to those who desire them. Support is obtained from the British Association, from the Royal Society, and private sources.

5. *Greece.*

D. Eginitis has published a catalogue of local disturbances, 1893–1898.

6. *Holland.*

The Magnetic and Meteorological Department in Batavia observes and publishes records relating to earthquakes of local and distant origin. Supported by the State.

7. *Hungary.*

Earthquakes are observed by a system similar to that adopted by Austria. At Buda Pest, Agram, O'Gylla, Fiume, and at a few other stations, instruments have been installed to record earthquakes with a distant origin.

8. *Italy.*

In Italy there are about 800 stations at which earthquakes are observed. Out of these there are fifteen first-class observatories provided with apparatus to record teleseisms and local shocks, and 150 second-class stations using seismoscopes. Since 1879 these have been under State control. The registers are published by the Central Meteorological Office in Rome, and to these are added corresponding records from nearly all the teleseismic stations of the world. This catalogue therefore practically contains the information relating to teleseisms contained in registers issued by all other nations. A few observatories, as, for example, those at Padua and Florence, also publish their records separately.

9. *Japan.*

Japan has at least five stations for teleseismic observations, and about eighty provided with instruments for recording local shocks. Records of these latter are made at over 1,000 centres, and as from 1,000 to 2,000 earthquakes are recorded annually, and as each of these may be noted at many centres, the number of manuscripts accumulating at the Central Observatory in Tokyo is very great. Accounts of the more important shocks are published in the 'Official Gazette' and in other newspapers.

A catalogue of 8,331 shocks (1885–1892) was published in the 'Seismological Journal,' and a similar but more extensive catalogue is now in progress.

The Earthquake Investigation Committee issue many publications relating to seismology, while papers on the same appear in the Tokyo Physico-Mathematical Society. Very many of the publications are in Chinese characters. At the University there is a Professor and an Assistant Professor of Seismology.

Practically all work is supported by the Government, the Investigation Committee alone receiving 1,000*l.* to 5,000*l.* a year.

10. *Norway.*

In connection with the Museum in Bergen Dr. Kolderup is issuing an annual list of earthquakes felt in Norway.

11. *Roumania.*

The 'Institut Météorologique de Roumanie' issues occasional sheets relating to teleseisms.

12. *Russia.*

In Russia and Siberia there are seven stations of the first order at which teleseismic and other shocks are recorded, and ten or twelve stations of the second order. Teleseismic records and special papers are published by the 'Commission Centrale Sismique Permanente.' Some of the stations, like Tiflis, Taschkent, and Irkutsk, also publish their records separately.

13. *Servia.*

Servia has a station in Belgrade.

14. *Switzerland.*

In 1880 F. A. Forrel and Heim arranged an organisation to collect records relating to shocks originating in Switzerland. These are published by the Meteorological Bureau.

15. *United States of North America.*

The Department of the Interior, in the monthly bulletin of the Philippine Weather Bureau, publish a list of teleseisms recorded in Manila, and a list of earthquakes recorded in the Philippines.

In California there are about twenty stations furnished with apparatus to record local disturbances. Lists are published in the Bulletin of the U.S. Geological Survey.

VII. *Directions in which Seismological Work may be extended.*

From the preceding section it may be inferred that at the present time there are about eighty stations at which teleseismic disturbances are recorded, and that nearly half of these are in Central Europe.

To obtain a fairly even distribution of stations over the surface of the world about twenty-three more places of observation are required. A possible distribution for these is as follows :—

Alaska, 1 ; U.S.A., Central Canada, Newfoundland, and Central America, 7 ; South America, 3 ; Iceland, 1 ; N. Norway, 1 ; Africa and Aden, 3 ; China, 2 ; the East Indies and the South Pacific, 5.

A more immediate requirement is, however, the establishment in and near to districts from which world-shaking earthquakes originate of sets of ordinary seismographs, together with the co-operation of observers provided with good time-keepers, or even fairly good watches. In districts remote from telegraphs or observatories these may be rated by sun observations. A simple method of making such an observation sometimes employed at Shide and Cassamiccola is as follows. In a brick wall facing south a hole has been made which on the outside is covered by two pieces of sheet iron brought together to leave a vertical slit about 5 mm ($\frac{1}{4}$ in.) in width and 40 cm. (16 in.) in height. The sun passing before this slit throws an image of the same upon the opposite wall 14 feet distant. On this wall opposite the slit and in a north-south plane with the same there is a vertical line. When the image reaches this, the sun is due south at an observed time. To the time when this occurs the equation of time is added or subtracted and local mean noon is obtained within about one second.

The object of these time observations, which may be made quite well with an ordinary watch, is to obtain the time of arrival of earth movement at various points round an epicentre, from which may be calculated

the positions of foci of world-shaking earthquakes, not alone from the initial disturbance, but also from 'after shocks,' which latter seldom reach distant places.

When we know these *foci*, local observations enable us to make close approximation to the times at which large earthquakes have originated; and when this is done our knowledge of the rates at which motion has been propagated in various directions through and round the world will become more reliable.

The districts where such observations are required are indicated on the map, Plate II.

District E (Japan) is already well supplied with seismographs. Districts requiring similar installations are: A (Alaska), B and C (Central America and the West Indies), and K (Caucasian Himalayan district). In each of these at least six seismographs and the means of obtaining good time are needed.

Other lines upon which geophysical and seismological research might be conducted, but which have hitherto received but small attention, are numerous. Our knowledge of earthquake movement as recorded underground as compared with that noted upon the surface requires extension. As far as we can learn from the excellent work inaugurated in the Adalbert Shaft at Pribram by Dr. Edmund V. Mojsisovics, it would appear that the movement, at a depth of 1,115 m., is for world-shaking disturbances practically identical with that noted on the surface, from which it may be inferred that for this class of earthquake the large waves are not a mere superficial disturbance of the earth's crust.

Whether suboceanic disturbances are accompanied by molar displacements and large changes in suboceanic configuration remains to be determined by soundings the results of which should be of value to the hydrographer.

The fact that at certain observatories unfelt teleseismic movements are accompanied by perturbations of magnetic needles, which disturbances remain without satisfactory explanation, suggests that if such irregular perturbations are due to the influence of local subjacent magnetic magmas, in such localities not only should magnetic intensity be abnormal, but also that the differences between the observed and calculated values for gravity should be unusual.

What are the relationships between seismic and volcanic activities? and, further, what are the relationships between such phenomena, changes of level, magnetic elements, and the value for gravity? are also questions the answers to which are at present largely based upon hypotheses.

The movements on fault lines which accompany earthquake disturbances require an extended investigation, while the relationship which appears to exist between the dip and strike of rock folds and earthquake movement is a subject that has received but little attention.

Much has already been done to establish a relationship between earthquake frequency and certain astronomical phenomena; but fields for investigation, as, for example, the connection between movements of the earth's crust and the wanderings of the pole, have yet to be exploited. Again, as bearing upon earthquake occurrence, secular movements of the earth's crust, as, for example, those which are evidenced by changes in water level, alterations in the lengths of base lines and levels, the increase or decrease in the water-holding capacity of certain basins, have yet to be subjected to extended and careful measurements.

The harmonisation of results obtained from seismometry relating to the probable nature of the interior of the world with the requirements of astronomy, geodesy, the revelations of the plumb-line and the thermometer, together with various branches of physical, chemical, and geological research, constitute inquiries of profound interest.

Surface warpings of the earth's crust due to lunar or tidal influence or the variations in load which accompany changes in meteorological conditions may not only have a bearing upon earthquake frequency, but also may throw light upon the variations in flow and the rise and fall of subterranean waters, the escape of gases, and even perhaps assist the meteorologist in his forecasts of the weather.

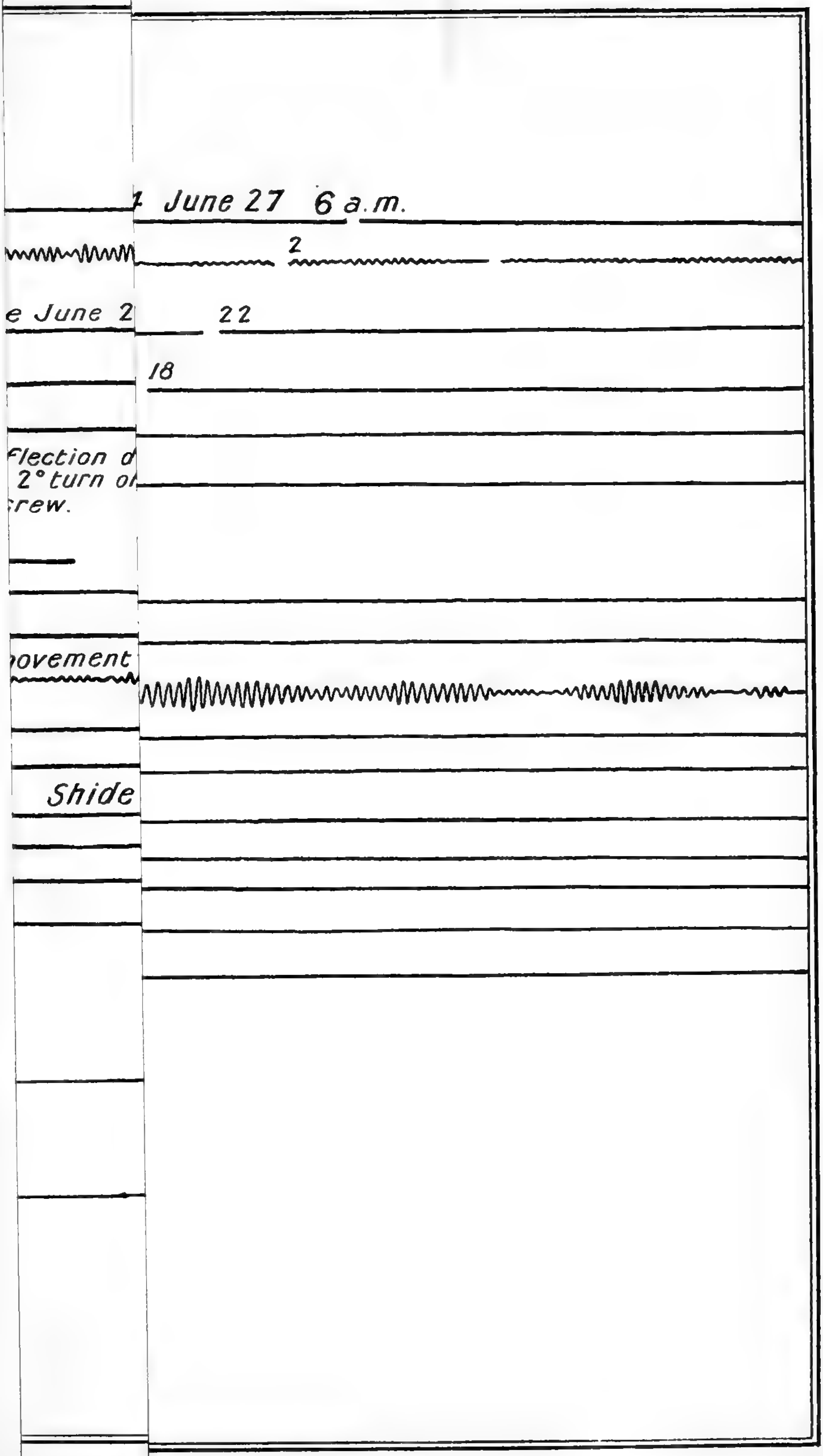
As illustrative of the practical outcome of seismological investigation the following may be mentioned :—

From observations on the destructive effects of earthquakes, the knowledge obtained respecting the actual nature of earthquake motion, and from experiments made upon brick and other structures, new rules and formulæ for the use of engineers and builders have been established. In Japan and other countries these have been extensively applied in the construction of piers for bridges, tall chimneys, walls, ordinary dwellings, embankments, reservoirs, &c. Inasmuch as the new types of structures have withstood violent earth-shakings, whilst ordinary types in the neighbourhood have failed, it may be inferred that much has already been accomplished to minimise the loss of life and property. These investigations have yet to be extended.

The application of seismometry to the working of railways, particularly in Japan, has led to the localisation of faults on lines and alterations in the balancing of locomotives. The result of the latter has been to decrease the consumption of fuel.

Records of the unfelt movements of earthquakes indicate the time, the position, and, what is of more importance, also the cause of certain cable interruptions. The practical importance of this latter information, especially to communities who may by cable failures be suddenly isolated from the rest of the world, is evident. The many occasions that earthquake records have furnished definite information respecting disasters which have taken place in distant countries, correcting and extending telegraphic reports relating to the same, is another indication of the practical utility of seismic observations. Seismograms have frequently apprised us of sea waves and violent earthquakes in districts from which it is impossible to receive telegrams, whilst the absence of such records has frequently indicated that information in newspapers has been without foundation, or at least exaggerated. The localisation of the origins of world-shaking earthquakes, besides indicating suboceanic sites of geological activity, have indicated positions where the hydrographer may expect to find unusual depths. They have also shown routes to be avoided by those who lay cables.

In addition to the above, a great proportion of which relates to what may be called the field work of seismology, there are many subjects bearing upon the same science which remain to be investigated within the walls of a laboratory ; and as it seldom happens that any one research fails to suggest new departures, the work of to-day implies new and extended investigations in the future.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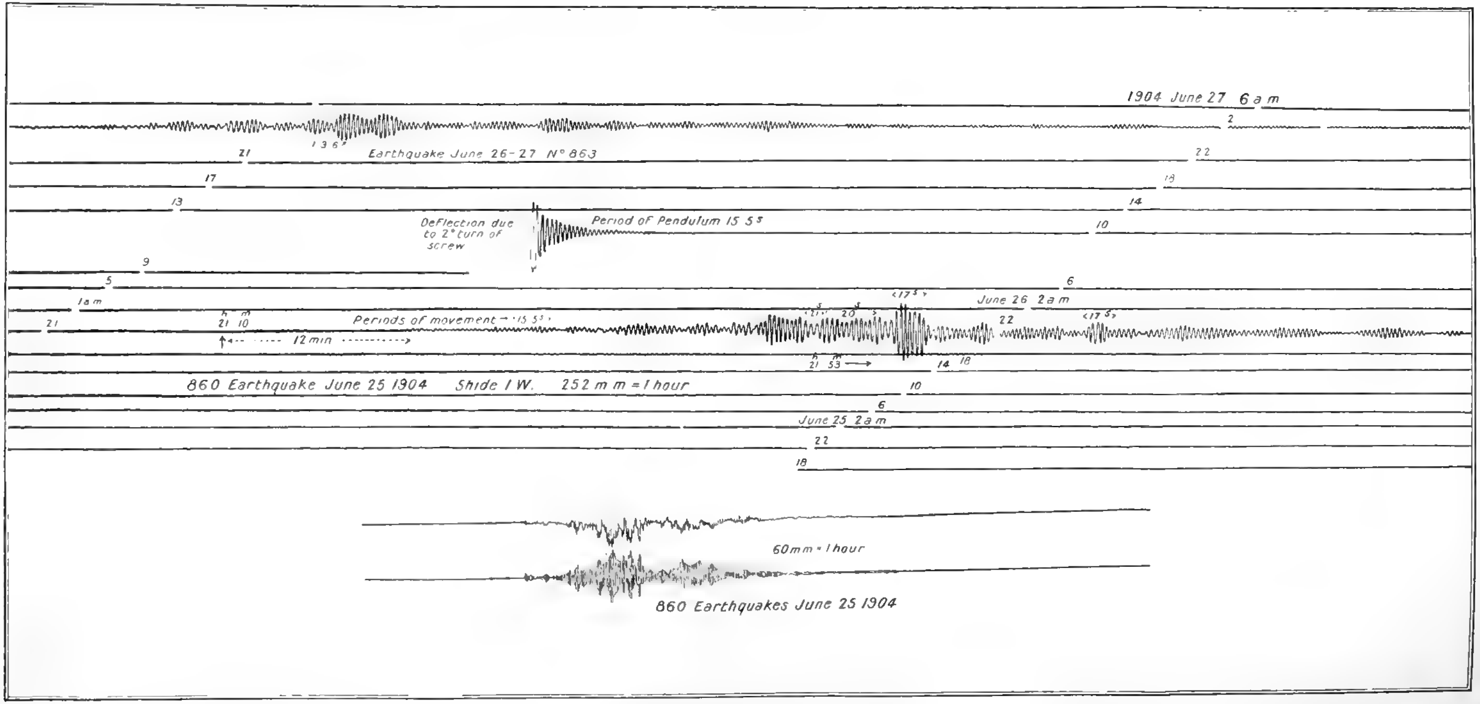

Illustrating the Report on Seismological Investigation.

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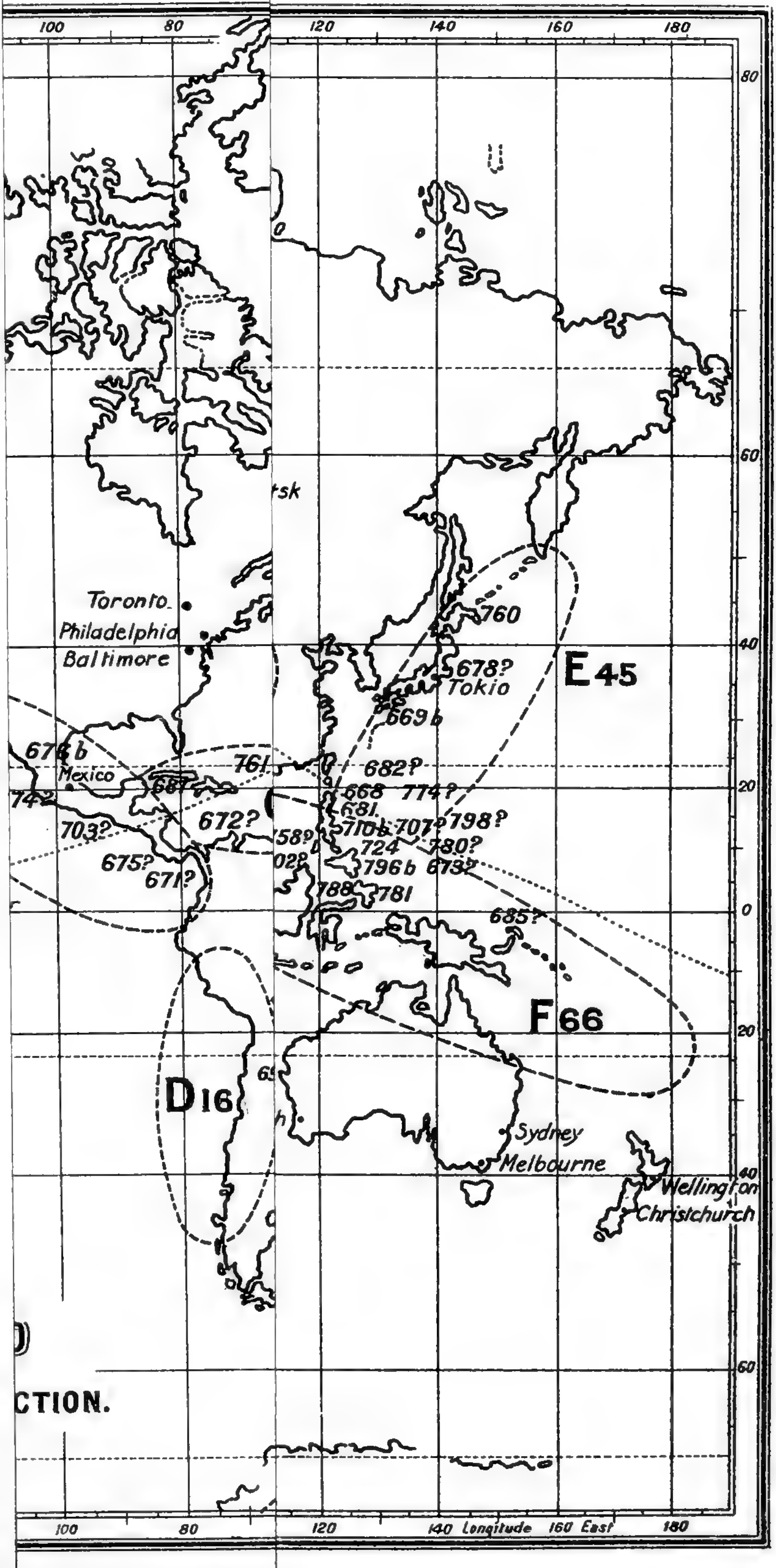
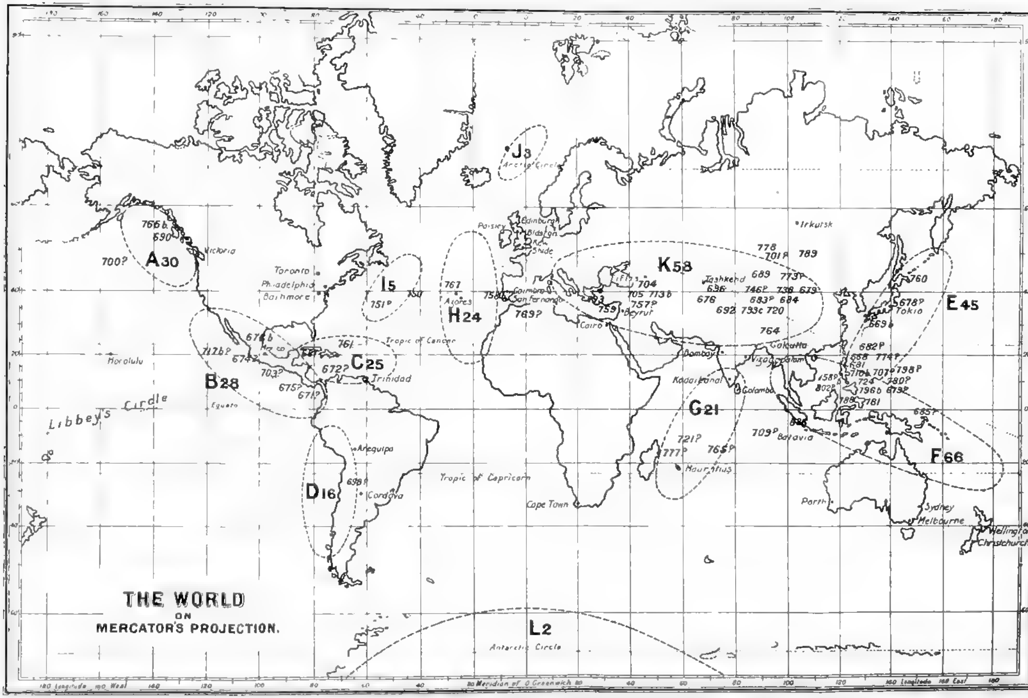


Origins for 1903 are indicated by their B.A. Shide Register number. Observing stations are named. Earthquake districts are indicated A, B, C, &c., and the number of earthquakes which since 1899 have originated from these is expressed in large numerals.



Illustrating the Report on Seismological Investigation.

VIII. *The Experiment at the Ridgeway Fault.*

Mr. Horace Darwin informs the Committee that he visited Upway in March last, when he took out most of the apparatus and put new in its place. This seems to be working well, and if it continues to do so he hopes to furnish a detailed report on the relative movements of the two sides of the fault next year.

Underground Temperature.—Twenty-third Report of the Committee, consisting of Professor J. D. EVERETT (*Chairman and Secretary*), Lord KELVIN, Sir ARCHIBALD GEIKIE, Professors EDWARD HULL, A. S. HERSCHEL, *and* G. A. LEBOUR, Messrs. A. B. WYNNE, W. GALLOWAY, JOSEPH DICKINSON, G. F. DEACON, E. WETHERED, *and* A. STRAHAN, Professors MICHIE SMITH *and* H. L. CALLENDAR, Mr. B. H. BROUGH, *and* Professor HAROLD B. DIXON, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.* (*Drawn up by the Secretary.*)

IN response to a pressing request from the Secretary for further information respecting the Calumet and Hecla mine, Professor Agassiz, in the spring of 1903, had all the observations (covering a period of ten years) tabulated and sent with sketches to Professor T. C. Chamberlin, head of the Geological Department of the University of Chicago, who undertook to superintend their examination. In February 1904 Professor Chamberlin wrote the Secretary to the effect that he had only been able to prepare a preliminary report of a tentative kind, and that the material must have more critical study before going into print. Subsequent information unofficially communicated renders it probable that the rate deduced will be between 1° in 120 feet and 1° in 130 feet.

The report of the Australian Association for the Advancement of Science for 1902 contains, at p. 309, an account, by Henry C. Jenkins (Government Metallurgist, Victoria), of observations of underground temperature in deep gold mines.

At the North Garden Gully mine, Bendigo, 99°·1 was found at 3,000 feet; and at New Chum Railway mine, Bendigo, 107°·0 was found at 3,645 feet. The mean surface temperature inferred from observations at 182 feet and 247 feet in neighbouring shallow shafts is 61°·4; which gives the rate as 1° F. for 80 feet at both these mines.

Electric-resistance platinum thermometers were used. Also slow-acting thermometers in which fine flannel is wrapped three times round the bulb, and the thermometer, with cork supports, then inclosed in a sealed glass tube.

A nearly identical rate was obtained in some preliminary observations which were taken in less favourable circumstances in a 1,700-foot heading at South German mine, Maldon, and at the depth of 2,080 feet in the Band and Albion mine, Ballarat. The rate 1° in 80 feet is exactly the same as that found by Professor David in a bore, 2,733 feet deep, near Port Jackson.[1]

A shaft 1,000 metres deep, recently sunk at the collieries of Ronchamp (Haute Saône) in East France, is described in a series of four articles, by

[1] See Report for 1895.

Mons. L. Possigue, in the 'Bulletin de la Société de l'Industrie Minérale' for 1903. The first 764 metres belong to the New Red Sandstone series, including Lias and Permian. The remainder include 112 m. of Upper Coal Measures, 66 m. of Lower Coal Measures, and 68 m. of Schists. The following rock temperatures were observed during the sinking :—

Depth	Temp. C.	Depth	Temp. C.	Depth	Temp. C.
M.	°	M.	°	M.	°
10	10·5	830	39·6	930	44·6
300	21·0	850	40·7	950	45·2
400	24·5	860	41·0	960	45·5
600	31·1	870	41·5	970	45·7
700	34·2	890	42·9	990	46·4
750	36·8	900	43·5	1000	46·8
800	38·3	910	43·8	1009	47·4

The shallowest, compared with the deepest, gives an increase of 36°·9 C. in 999 m., which is at the rate of 1° C. in 27·1 m., or 1° F. in 49·4 feet.

When the observations are plotted they show nearly a straight line from 10 m. to 600 m., its gradient being 1° C. in 28·6 m. (1° F. in 52 feet), and the remaining portion from 600 m. to 1,009 m. oscillates about a line whose gradient is 1° C. in 25·1 m. (1° F. in 46 feet).

Regular observations of temperature have been taken in the Simplon Tunnel, of which only about half a kilometre remains to be pierced. On its completion Mr. Francis Fox promises a full account of the temperatures, which will probably be communicated to one of the London societies before the end of the present year.

A large body of evidence on temperatures in deep coal mines is contained in the report recently published by the Royal Commission on Coal Supplies. The chief element of uncertainty in discussing the observations is the mean surface temperature, which has in most cases not been directly observed, and is doubtful to the extent of 1° or more. The following list of well-determined mean surface temperatures (chiefly from the publications of the Royal Meteorological Society) seems to constitute the best material for forming a judgment. They are for moderate elevations, except where otherwise stated :—

Camden Square, London	49°·2
Bolton	49°·2
North Thoresby (Linc.)	49°·2
Rounton (North Yorks.)	47°·3
Ashton-under-Lyne (elevation 405 feet)	46°·5

At Pendleton, near Manchester, Mr. H. Bramall took observations in the Rams mine and in the Agecroft Colliery. The deepest observation was at 3 483 feet from the surface in the Rams mine, the temperature found being 100°, as shown by a thermometer left for three hours in a hole bored $3\frac{1}{2}$ feet into the rock and covered with a piece of cotton waste. Assuming a surface temperature 47°, we have an increase of 53° in 3,483 feet, or 1° in 66 feet. If we take the surface temperature as 48°, it is 1° in 67 feet.

At Agecroft Colliery the deepest observation was 92°·5 at 2,940 feet ; which with an assumed surface temperature 47°·5 gives 1° in 65 feet.

The above-named temperature in the Rams mine was checked by

Professor Harold Dixon in October 1902 with a slow-acting thermometer made by Negretti & Zambra and tested at Kew inserted in a hole 4 feet deep in the floor at the lowest point reached.

The reading obtained was 100°·6, which confirms the deduction of 1° in 66 feet.

In the North Staffordshire coalfield Mr. W. N. Atkinson, H.M. Inspector of Mines, found the following temperatures at the greatest depths reached :—

Sneyd Colliery, Burslem . . .	87°·5	at	2,625 feet.
Glebe Colliery	$83\frac{1}{4}$°	,,	2,295 ,,
Great Fenton Colliery . . .	85°·0	,,	2,400 ,,

Assuming 48° as the surface temperature, the mean rates of increase downwards are :—

Sneyd	1°	in	66·5 feet.
Glebe	1°	,,	65·1 ,,
Great Fenton	1°	,,	64·9 ,,

The method of observation was to drill a hole, insert a bottle of water, and, after leaving it in the hole, plugged with clay, for twenty-four hours or more, take it out, and put a thermometer into the water in the bottle. In the Sneyd Colliery observations were thus taken at thirteen depths during the sinking of a shaft, beginning with 1,104 feet and ending with 2,625 feet, and the increase shown was fairly regular. The Glebe and Great Fenton observations were also in sinking shafts.

At Hamstead Colliery in South Staffordshire Mr. F. G. Meachem made observations extending over several years. He found the mean annual surface temperature to be about 49°, and the temperature of the undisturbed strata at the bottom, 1,950 feet deep, 66°. This last was ascertained by inserting a maximum and minimum thermometer, protected by a metal case, into a bore-hole driven ten feet into freshly cut coal. The hole was closed with clay and left for various periods from one to fourteen days.

Repeated observations gave the same result. The rate of interest hence deduced is 1° in 115 feet. A surface temperature of 48° would give 1° in 108 feet. Mr. Meachem himself says : 'All observations show an increase of temperature in undisturbed strata of 1° F. for every 110 feet of descent beyond 65 feet from the surface.'[1]

Mr. W. N. Atkinson[2] obtained a nearly identical rate at a new shaft at Baggeridge Wood, S. Staffs ; but the circumstances were unfavourable, the shaft being wet, and the observations not made till about a week after the sinking was finished. The temperature thus found was $66\frac{1}{2}$° at a depth of 1841 feet. Assuming a surface temperature $48\frac{1}{2}$°, this is an increase of 1° in 102 feet. The Secretary has made inquiries to ascertain whether these very slow increases in South Staffordshire can be due to steep inclination. He learns from Mr. W. N. Atkinson that the strata in South Staffordshire generally are very flat and nearly level. At Hamstead the inclination averages only one in 55 (or, according to Mr. Meachem, 1 in 19). In North Staffordshire, on the other hand, the strata are much contorted, and the inclinations at Glebe, Great Fenton, and Sneyd range from 1 in 10 to 1 in 5. The suggested explanation of the difference therefore completely breaks down.

[1] *Trans. Inst. Min. Eng.*, vol. xxv. 1903, p. 271.
[2] Q. 2295 in Report of Commission.

In South Wales, in the neighbourhood of Rhondda and Aberdare, Mr. William Jenkins has taken numerous observations by a somewhat rough method, an ordinary thermometer being inserted in a hole bored 3 feet deep into the coal, with an oiled waste plugging, and taken out from time to time and reinserted till the temperature was steady, the whole time being upwards of an hour. The observations were made in various seams at depths below the surface ranging from 1,094 feet to 2,515 feet, with very varying results, the surface being 875 feet above sea-level. Taking the surface temperature as 47°, and comparing it with the deepest observation (73½° at 2,515 feet), we have an increase of 26½° in 2,515 feet, which is at the rate of 1° in 95 feet; but the mode of observation is unsatisfactory.

At Dowlais, in the Merthyr coalfield, Mr. H. W. Martin has taken numerous observations in several collieries by means of thermometers inserted in boreholes and left for about twenty-four hours, the instruments being apparently strong thermometers specially ordered from a local optician. The greatest depth below the surface was 2,600 feet, with temperature 77°. Assuming the surface temperature to be 49°, this gives a rate of 1° in 93 feet. The inclination of the strata averages about 1 in 7.

At the Niddrie Collieries, near Edinburgh, Mr. Robert Martin has made observations in the Great Seam at the depth of 2,623 feet, and finds the 'temperature in the solid coal face' at this depth to be 74°. The surface ground temperatures found at four surrounding stations of the Scottish Meteorological Society (Joppa, Nookton, East Linton, Smeaton) are 46°·1, 47°·6, 47°·7, 47°·9. Assuming a surface temperature of 47°·5, we have an increase at the rate of 1° in 99 feet. The strata are highly inclined, the dip ranging from 50° to 90°; a circumstance conducive to a slow rate of increase.

Hofrat Prof. H. Höfer, of Leoben, Austria, has recently issued, with the sanction of the Austrian mining authorities, a circular giving directions for the taking of temperature observations during the sinking of mining shafts, and has since been furnished, at his own request, with copies of most of the reports of your Committee. The circular recommends the use of maximum thermometers, divided to fifths of a degree centigrade, to be inserted in holes bored to the depth of at least 2 metres in the floor or side and well plugged. The observations are to begin at 25 m. from the surface, to be repeated at intervals of 50 m. till a coal seam is approached, and then at shorter intervals through and a little beyond the seam. This process is to be repeated for every seam that is traversed. A main purpose of the investigation[1] is to determine the influence of coal seams on the temperature of their surroundings. Hot springs have been encountered in several Austrian coal mines, and Professor Höfer ascribes their heat to chemical changes in the coal. In this connection it may be mentioned that much evidence has come before the Coal Commission of spontaneous heating of coal by exposure to the air. According to Professor Höfer the greatest heating occurs in brown coal.

It seems desirable at this time to make more generally known to observers of rock temperature in mines that the simple and strong pattern of slow-action thermometer, designed by your Committee many years ago for this purpose, is still obtainable from the makers, Messrs. Negretti &

[1] *Oester. Zeitschrift für Berg- und Hüttenwesen*, 1901, p. 249, &c. Also paper to Institution of Mining Engineers, London Conference, 1904.

Zambra. It is a mercurial thermometer, with extra-thick bulb, imbedded in stearine, the whole being inclosed in a hermetically sealed glass tube with a perforated copper case for protection against breakage.

Professor Harold Dixon, F.R.S., who has taken a leading part in the underground temperature work of the Coal Commission, has been added to the Committee; and two old members, Mr. James Glaisher, F.R.S., and Sir C. Le Neve Foster, F.R.S., have been lost by death. Mr. Glaisher was one of the most active members of the Committee for the first fifteen years of its existence.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren, Professor A. Crum Brown (*Secretary*), Sir John Murray, Dr. Alexander Buchan, *and* Mr. R. T. Omond. (*Drawn up by* Dr. Buchan.)

The Committee was appointed, as formerly, for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations have been made at the high-level Observatory by Mr. Rankin and his assistants uninterruptedly during the year. At the low-level Observatory in Fort William the self-registering instruments have been in continuous use throughout the year.

The health of the observers has been good. Mr. Robert H. Macdougal, who has been on the staff for many years, left the Observatory in December, and Mr. W. L. A. Craig Christie was appointed. The Directors desire to thank cordially Messrs. W. G. MacConnachie, A. J. Ross, and J. H. Buchanan for their valuable services as volunteer observers while members of the ordinary staff were on holiday last summer.

The results of the observations made at the two Observatories during 1903 are detailed in Table I.

TABLE I.

1903	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Mean Pressure in Inches.							
Ben Nevis Observatory	25·099	25·148	24·915	25·232	25·325	25·555	25·360	25·189	25·405	24·925	25·315	25·056	25·210
Fort William	29·720	29·726	29·475	29·845	29·863	30·088	29·847	29·659	29·924	29·410	29·915	29·650	29·760
Differences .	4·621	4·578	4·560	4·613	4·538	4·533	4·487	4·470	4·519	4·485	4·600	4·594	4·550
						Mean Temperatures.							
Ben Nevis Observatory	22°·7	27°·3	24°·6	24°·5	33°·4	38°·7	39°·8	37°·6	37°·3	31°·7	28°·3	24°·2	30°·8
Fort William	38·5	43·2	41·5	42·7	49·7	53·9	55·1	53·9	53·6	47·8	43·5	38·5	46·8
Differences .	15·8	15·9	16·9	18·2	16·3	15·2	15·3	16·3	16·3	16·1	15·2	14·3	16·0
						Extremes of Temperature: Maxima.							
Ben Nevis Observatory	35·7	42·3	37·0	35·0	56·0	58·0	49·6	49·0	50·0	40·5	41·9	36·6	58·0
Fort William	50·4	55·6	56·5	57·6	71·5	76·0	71·1	63·8	68·0	60·0	55·5	54·0	76·0
Differences .	14·7	13·3	19·5	22·6	15·5	18·0	21·5	14·8	18·0	19·5	13·6	17·4	18·0
						Extremes of Temperature: Minima.							
Ben Nevis Observatory	7·7	17·0	14·9	12·6	15·7	22·8	27·7	31·0	24·3	22·8	10·9	13·3	7·7
Fort William	21·3	32·1	32·3	29·6	33·4	36·2	40·6	42·2	35·8	31·0	23·5	22·4	21·3
Differences .	13·6	15·1	17·4	17·0	17·7	13·4	12·9	11·2	11·5	8·2	12·6	9·1	13·6

TABLE I.—*continued.*

1903	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Rainfall in Inches.							
Ben Nevis Observatory	33·45	36·24	37·95	8·36	6·61	6·44	13·26	20·97	10·72	18·66	17·27	6·81	216·74
Fort William	16·12	17·04	17·25	3·81	4·49	2·97	6·60	11·95	7·15	13·05	7·85	5·61	113·89
Differences	17·33	19 20	20·70	4·55	2·12	3·47	6·66	9·02	3·57	5·61	9·42	1·20	102·85
						Number of Days 1 *in. or more fell.*							
Ben Nevis Observatory	11	13	17	4	1	2	5	7	3	8	5	3	79
Fort William	5	7	7	0	1	0	1	3	1	4	1	2	32
Differences .	6	6	10	4	0	2	4	4	2	4	4	1	47
						Number of Days 0·01 *in. or more fell.*							
Ben Nevis Observatory	22	27	28	22	19	18	23	29	18	29	22	23	280
Fort William	21	26	31	13	16	12	21	27	21	29	22	20	259
Differences .	1	1	−3	9	3	6	2	2	−3	0	0	3	21
						Mean Rainband (Scale 0–8).							
Ben Nevis Observatory	1·4	2·4	2·0	2·0	2·3	3·6	2·7	2·6	2·5	3·3	2·5	1·5	2·4
Fort William	3·6	4·8	3·9	3·1	3·8	4·7	4·7	4·7	4·0	4·5	4 0	3·4	4·1
Differences .	2·2	2·4	1·9	1·1	1·5	1·1	2·0	2·1	1·5	1·2	1·5	1·9	1 7
						Number of Hours of Bright Sunshine.							
Ben Nevis Observatory	16	5	11	40	79	137	76	23	67	16	21	18	509
Fort William	22	10	39	120	135	178	141	91	126	36	21	15	934
Differences .	6	5	28	80	56	41	65	68	59	20	0	+3	425
						Mean Hourly Velocity of Wind in Miles.							
Ben Nevis Observatory	22	17	17	11	11	9	11	12	20	18	9	19	15
						Percentage of Cloud.							
Ben Nevis Observatory	88	98	95	80	82	74	86	95	80	96	89	93	87
Fort William	73	88	85	74	73	68	75	83	66	89	80	77	78
Differences .	15	10	10	6	9	6	11	12	14	7	9	6	9

The above table shows for 1903 the monthly mean and extreme temperature and pressure ; the amounts of rainfall ; the number of days of rainfall, and of the days on which it equalled or exceeded an inch ; the hours of sunshine ; the mean rainband ; the mean velocity in miles per hour of the wind at the top of the mountain ; and the mean cloud amount. The mean barometric pressures at Fort William are reduced to 32° and sea-level ; but those at Ben Nevis Observatory to 32° only.

At Fort William the mean atmospheric pressure was 29·760 inches, or 0·098 inch below the average of thirteen years ; whilst the mean at the top was 25·210 inches, or 0·090 inch below the average of twenty years. The mean difference for the two Observatories was 4·550 inches, the mean monthly difference varying from 4·621 inches in January to 4·470 inches in August. At both places the mean for the year was considerably lower than any hitherto recorded, and only in June, September, and November were the monthly means above their normals. The means for October were much lower than any yet recorded for that month, the deficiency at Fort William being as much as 0·365 inch. At the top the absolutely highest pressure for the year was 25·941 inches at 2 P.M. on May 26, and the lowest 23·916 inches at 5 A.M. on February 27. At Fort William the extremes were 30·572 inches at 10 A.M. on November 6, and

28·326 inches at 6 A.M. on February 27. The extreme range on Ben Nevis was, therefore, 2·025 inches, and at Fort William 2·246 inches.

The deviations of the mean temperatures of the months from averages of the thirteen years (1891–1903) are shown in Table II. :—

TABLE II.

	Fort William.	Top of Ben Nevis.		Fort William.	Top of Ben Nevis.
	°	°		°	°
January	−0·2	−0·7	July	−2·0	−1·9
February	+4·6	+3·2	August	−2·6	−3·2
March	+1·1	+0·3	September	+0·4	−0·7
April	−2·4	−3·8	October	+1·2	+0·3
May	+0·0	+0·2	November	−0·5	−1·2
June	−1·5	−1·3	December	−1·6	−1·5

The most remarkable features of the year as regards temperature were the low temperatures for April and the cold weather of the summer months. At both Observatories the April mean temperatures were the lowest recorded for that month since 1891, the shade minimum at Fort William registering frost from 12th to 18th, and on 22nd and 24th ; whilst on Ben Nevis the minimum fell to 12°·6 on 17th, and the maximum rose above the freezing-point on only eleven days of the month, the highest shade reading there being no higher than 35°·0, on the 6th and 9th. The absolutely highest temperature for the year at Fort William was 76°·0 on June 7, and at the top 58°·0 on the same day ; the lowest at Fort William being 21°·3 on January 13, and at the top 7°·7 on January 10.

In Table III. are given for each month the lowest observed hygrometric readings at the top of Ben Nevis (reduced by means of Glaisher's Tables) :—

TABLE III.

1903	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	19°·1	42°·2	22°·6	16°·1	42°·0	47°·3	39°·8	42°·7	40°·6	31°·0	23°·0	21°·0
Wet Bulb	15·3	32·0	18·1	14·1	32·0	33·5	30·9	32·8	30·3	25·6	19·0	15·7
Dew-point	−12·4	20·2	−10·7	−1·3	20·0	18·3	19·3	20·9	16·9	11·0	−6·2	−20·9
Elastic Force	·024	·109	·025	·041	·108	·099	·104	·112	·093	·071	·032	·016
Relative Humidity [Sat.=100]	23	41	21	46	40	30	42	41	37	41	26	14
Day of Month	8	9	3	18	29	5	8	1	16	18	18	29
Month of Year	23	17	17	1	2	24	2	2	9	9	3	23

Of these relative humidities, the lowest, 14 per cent., occurred on December 29 with a dew-point of −20°·9, that being the lowest dew-point for the year. From 9 A.M. on January 21 to noon on February 9—that is, for a period of 507 hours—the atmosphere was continuously in a saturated condition, the summit of the mountain being wreathed in fog or mist throughout the period, except for one short break of three hours. The next longest periods of continuous saturation were from April 3 to 11, from September 3 to 10, and from December 9 to 17.

The rainfall for the year at the top was 216·74 inches, or 55·97 inches above the average of 19 years; whilst the annual amount at Fort William was 113·89 inches, or 35·31 inches above the average for the same period. At Fort William the year was the wettest hitherto recorded, but on Ben

Nevis the amount was considerably below that for 1898, when the total was as much as 240·12 inches. On Ben Nevis the totals for January, February, March and August were the largest hitherto recorded for these months, whilst the aggregate for the first three months was half the total for the year and considerably more than twice the average. At Fort William, also, about half the annual amount was registered during the first three months, whilst the aggregate for that period was more than twice the average. At the top of the mountain the greatest fall recorded on a single day was 4·78 inches on January 29, the corresponding fall at Fort William being 1·78 inch; whilst the maximum daily amount at Fort William was 3·09 inches on January 25, the fall at the top on that day being 3·03 inches.

At the top of Ben Nevis the number of rainy days was 280, or 17 above the average, and at Fort William 259 days, or 25 above the average. The number of days on which 1 inch or more fell was much above the average at both observatories, Ben Nevis having no fewer than 79 such days, or 26 above the average, and Fort William 32, or 17 above the average. Of these days of heavy falls, as many as 41 occurred at Ben Nevis during the first three months of the year, and as many as 19 at Fort William. Considering also daily falls of between 0·50 inch and 0·99 inch, and less heavy falls, we have the following table:

Daily Falls of	Aggregate of Falls		Number of Days	
	B.N.O.	F.W.	B.N.O.	F.W.
1 in. and over	149·4 in.	51·3 in.	79	32
$\frac{1}{2}$ in. to 0·99 in.	39·0 ,,	32·1 ,,	52	46
Less than $\frac{1}{2}$ in.	28·3 ,,	30·5 ,,	149	181
Total	216·7 ,,	113·9 ,,	280	259

Thus, on Ben Nevis nearly half, and at Fort William nearly one-third, of the number of rainy days had falls of half an inch or over, whilst at the top of the mountain such falls contributed six-sevenths of the total for the year. Again, at Fort William 45 per cent. of the annual amount was due to daily falls of 1 inch or over, and at the high-level station nearly 70 per cent. to such heavy falls.

The sunshine recorder on Ben Nevis registered 509 hours out of a total possible of 4,473 hours, or 11·4 per cent. of the possible sunshine, being 227 hours below the average of twenty years. This is the smallest annual amount recorded since the Observatory was opened, the next least sunny years being 1884 with 524 hours, 1886 with 571, and 1890 with 591. The amounts for February and March were the least on record for these months, and only in June, September, and December were the totals above the average, and that by very small amounts. At Fort William the annual amount was 934 hours, being the smallest total in thirteen years and 185 hours below the average for that period. February, March, and October had the smallest amounts on record for these months, the total of 10 hours in February being only one-fifth of the average for that month.

On Ben Nevis the mean percentage of cloud was 87, and at Fort William 78, both above the average. February, March, August and October were very cloudy months, the eye estimations of cloud amount

agreeing with the small amount of sunshine registered by the sunshine recorder.

On Ben Nevis the following phenomena were observed :—

Auroras :—September 20 ; November 1 ; December 25.

St. Elmo's Fire :—January 3, 6, 27, 28 ; February 27 ; March 5, 17, 27 ; May 16 ; July 23 ; August 3, 15, 18, 19, 20, 21 ; September 2, 10 ; October 5, 15, 16.

Thunder and Lightning :—July 2 ; August 15, 19, 20, 24.

Thunder only :—June 25, 29.

Lightning only :—January 26, 27 ; February 20, 25 ; March 5, 30 ; June 29.

Solar Halos :—April 19 (with Mock Suns) ; June 29.

Lunar Halos :—January 5, 8 ; February 9 ; July 31 ; December 1.

In November 1903 the Deutsche Seewarte at Hamburg, Germany, applied to the Directors for daily telegrams from the Fort William and Ben Nevis Observatories, with a view to their use, along with similar data from Continental high-level stations, in aiding the preparation for the daily forecasts for the German Empire. These telegrams have accordingly been sent for several months past, and appear regularly in the Daily Weather Report issued by the 'Seewarte.'

Copies of the Ben Nevis observations have also been sent on application to Dr. Hergesell, to be used in connection with the International Aëronautical Investigation.

The discussion of the Ben Nevis observations on the lines indicated in our last year's Report has been continued. The chief subjects taken up by Dr. Buchan have been a continuation of the inquiry into the relations of temperature and pressure at the two Observatories, more particularly in regard to the great movements of the atmosphere grouped under the cyclone and the anticyclone. The observations have been sorted out into the following four classes :—

1. The data for the mean hourly differences of the sea-level pressures and temperatures for the months, including all types of weather, with the exception of those days on which strong winds occurred, which rendered the barometric readings untrustworthy owing to the pumping of the mercury.

2. The second class included all those days during the fourteen years on which the difference of temperature, *on the mean of the whole day*, was 12°·0 or less.

3. The third class included those days on which the difference of temperature was 18°·0 or upwards.

4. All the other days were grouped under this class on which the difference of temperature lay between 12°·0 and 18°·0, showing thus the results for the days when the temperature differences were virtually about the average.

This fourth class has been added to the investigation since the meeting of the British Association at Southport. Further, the averages for these four different classes have been now calculated from all the available observations made at the two Observatories from August 1900 to December 1903.

The broad results are these :—(1) When the difference of the mean

temperatures of the day is only 12°·0, or less, the calculated sea-level pressure for the top of the mountain is markedly greater than at Fort William, and the accompanying meteorological conditions are anti-cyclonic, the weather being clear, dry, and practically rainless ; (2) when the difference of temperature is 18°·0, or greater, the meteorological conditions are cyclonic, and the accompanying weather dull, humid, and rainy.

The large result here arrived at empirically is in accordance with the principle laid down by Dalton—viz., that air charged with vapour or vaporised air is specifically lighter than when without the vapour ; or, in other words, the more vapour any given quantity of atmospheric air has in it the less is its specific gravity.

Another important result is that the cases of small differences of temperature between the two Observatories are chiefly occasioned by an increase of temperature at the top of the mountain, and large differences of temperature by a decrease of temperature at the top.

The intimate relation thus disclosed between the varying temperatures and sea-level pressures of a high-level and a low-level station is of prime importance in forecasting the weather, inasmuch as it reveals, in a way not hitherto attempted, the varying conditions of the hygrometric states of the atmosphere, particularly at high levels, upon which changes of weather so largely depend. The setting in of a process of saturation of the atmosphere at great heights may thus be made known, even when no cloud has yet been formed to indicate any such saturation. The important bearing of these results on such practical problems in meteorology as the forecasting of the monsoons of India is evident.

The Study of Hydro-aromatic Substances.—Report of the Committee, consisting of Dr. E. DIVERS (*Chairman*), Dr. A. W. CROSSLEY (*Secretary*), Professor W. H. PERKIN, Dr. M. O. FORSTER, *and* Dr. H. R. LE SUEUR.

Recent Work on Hydro-aromatic Substances. *By* Dr. A. W. CROSSLEY.

THE following is a summary of the work published on hydro-aromatic compounds since the preparation of the last report.[1]

Petroleum.—Roumanian petroleum[2] resembles Russian and American petroleum, inasmuch as the densities of fractions taken every 2° between 50° and 70° diminish to a minimum at 60° to 62°, and then continuously increase, whilst in the case of Galician oil there is a steady increase of density throughout. A further difference from this latter oil is to be found in the composition of the fractions between 60° to 100°, which do not contain secondary hexanes, as on nitration they yield aromatic derivatives only. Methyl- and ethyl-hexahydrobenzene are among the hydrocarbons contained in the Roumanian oil.

Hydrocarbons.—Sabatier and Senderens[3] have shown that, when benzene or its homologues, containing methyl groups as side-chains, are passed together with hydrogen over reduced nickel, hydrogenation takes place without complication ; whereas if the hydrocarbons contain longer

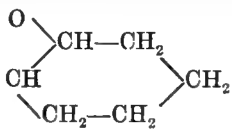
[1] Reports, 1903, p. 179.
[2] Poni, *J. C. S.*, 1903, Abst. (1), 593.
[3] *Compt. Rend.*, 1901, **132**, 1254.

side-chains (ethyl, propyl, &c.) part of the latter is split off. For example, ethylbenzene gives principally ethylhexahydrobenzene, but also small amounts of methylhexahydrobenzene. Sabatier and Mailhe[1] have further investigated the product obtained by passing benzene and hydrogen over reduced nickel, and find that if the temperature be maintained at 250° pure hexahydrobenzene is formed, identical in all respects with that occurring in Caucasian petroleum. If hexahydrobenzene be passed over reduced nickel at 270° to 280°, it is decomposed into benzene and hydrogen, which latter reacts with the benzene, forming methane. An energetic substitution reaction takes place when chlorine acts on hexahydrobenzene at a temperature of 0°, resulting in the formation of a mixture of mono-, di-, tri-, tetra-, and hexa-chloro- derivatives.[2]

According to Markownikoff,[3] methylhexahydrobenzene has not been obtained pure by the methods so far described; for example, when isolated from Caucasian petroleum, it is contaminated with normal heptane. It can, however, be prepared in the pure condition by the action of zinc dust on an aqueous alcoholic solution of 3-bromo-1-methylhexahydrobenzene. The hydrocarbon obtained by eliminating the elements of hydrogen bromide from this latter substance[4] is a mixture of the two methyltetrahydrobenzenes with the double bonds in the 2 : 3 and 3 : 4 positions. The pure substances have been obtained by other methods.[5] In such hydrocarbons the influence of the side-chain is such that in the splitting off of hydrogen together with a halogen, or in the combination with a molecule containing mobile hydrogen, the latter splits off from, or combines preferably with, the carbon atom furthest removed from the side-chain, whilst the electronegative element combines with the carbon nearest the side-chain. 1 : 1 : 3-trimethyl-Δ^3-tetrahydrobenzene.[6]

Hydroxy-derivatives.—The reaction introduced by Sabatier and Senderens has been extended to the preparation of aromatic alcohols. When phenol is passed together with excess of hydrogen over reduced nickel at a temperature of 140°–160°, pure hydroxyhexahydrobenzene is obtained;[7] but if the temperature be raised to 215°–230°, the hydroxyhexahydrobenzene first formed is decomposed into ketohexahydrobenzene and hydrogen. From the mixture so produced Sabatier and Senderens have obtained the pure alcohol or ketone by, in the first case, passing the product with excess of hydrogen over reduced nickel at a temperature of 140°–150°, and in the second by passing the product without hydrogen over reduced copper at a temperature of 330°. Under similar conditions thymol and carvacrol are converted into the corresponding hexahydro-derivatives (Brunel).

Iodohydroxyhexahydrobenzene gives, when treated with potash or silver oxide,[8] the internal oxide of 1 : 2-dihydroxyhexahydrobenzene,



[1] *Compt. Rend.*, 1903, **137**, 240.
[2] *Bull. Soc.*, 1903, **29**, 974.
[3] *Cent. Blatt.*, 1904 (**1**), 1345.
[4] *Cent. Blatt.*, 1904 (**1**), 1346.
[5] *Cent. Blatt.*, 1903 (**2**), 289; 1904 (**1**), 1213; Wallach, *Annalen*, 1903, **329**, 368.
[6] Harries and Weil, *Ber.*, 1904, **37**, 848.
[7] Holleman, *Cent. Blatt.*, 1904 (**1**), 727; Brunel, *Compt. Rend.*, 1903, **137**, 1268; Sabatier and Senderens, *ibid.*, 1903, **137**, 1025.
[8] Brunel, *Compt. Rend.*, 1903, **137**, 62.

into which substance the former is easily converted by the action of water. When the internal oxide is treated with alcoholic ammonia,[1] there result 1-amino-2-hydroxyhexahydrobenzene and two forms of dihydroxycyclohexylamine, $NH(C_6H_{10}.OH)_2$.

Power and Tutin [2] have isolated a lævorotatory modification of quercitol from the leaves of *Gymnema sylvestre.* It is demonstrated that this substance has the same constitution as *d*-quercitol (pentahydroxyhexahydrobenzene) which has been established by Kiliani and Schaefer,[3] and can only differ from the latter stereochemically; but, since *d*-quercitol has $(\alpha)_d + 24°\cdot16$, whilst the new quercitol has $(\alpha)_d - 73°\cdot9$, the one cannot be the optical antipode of the other. Eight optically active modifications of pentahydroxyhexahydrobenzene are possible, and until a further number of these isomerides are known it is impossible to assign a definite configuration either to *d*-quercitol or to the new l-quercitol.

Aldehydes and Ketones.—The general method for the preparation of aldehydes by the action of organomagnesium haloids on the esters of orthoformic acid dissolved in dry ether [4] appears to be applicable to the synthesis of hydro-aromatic aldehydes,[5] and in this way hexahydro-*m*-toluic aldehyde has been prepared from 3-bromo-1-methylhexahydrobenzene.

The preparation of hexahydrobenzyl alcohol [6] has been described by Bouveault. Methylhexylcarbinol, $C_6H_{11}.CH(CH_3)OH$, is obtained when acetic aldehyde is allowed to act on the magnesium compound of chlorohexahydrobenzene.[7] When these alcohols are oxidised with chromic acid the former yields hexahydrobenzaldehyde and the latter hexahydroacetophenone.

Chloro- derivatives of ketomethyldihydrobenzene.[8]

Acids.—When pentane-$\alpha\gamma\epsilon$-tricarboxylic acid is digested with acetic anhydride and then distilled,[9] a remarkable decomposition takes place with elimination of carbon dioxide and water and formation of δ-ketohexahydrobenzoic acid.

$$CO_2H \cdot CH\left\langle \begin{array}{l} CH_2-CH_2-CO_2H \\ CH_2-CH_2\cdot CO_2H \end{array} \right. = CO_2H \cdot CH\left\langle \begin{array}{l} CH_2-CH_2 \\ CH_2-CH_2 \end{array} \right\rangle CO + CO_2 + H_2O$$

On reduction the corresponding hydroxy- acid is obtained, which yields trans-δ-bromohexahydrobenzoic acid when treated with hydrogen bromide, and this bromo- acid, under the influence of sodium carbonate, gives rise to Δ^3-tetrahydrobenzoic acid. δ-Ketohexahydrobenzoic acid combines with hydrogen cyanide to form the mixed nitriles of the *cis*- and *trans*-modifications of α-hydroxyhexahydroterephthalic acid. Both the corresponding acids decompose on distillation with formation of Δ^1-tetrahydroterephthalic acid, identical with the acid synthesised by Baeyer.[10]

δ-Ketohexahydrobenzoic acid has been used by Perkin [11] as the starting-point for the synthetical preparation of terpin, inactive terpineol, and dipentene; but as this report does not include a consideration of the terpenes and camphors, an account of this work is not given.

[1] Brunel, *ibid.*, 1903, **137**, 198.
[2] *J. C. S.*, 1904, **85**, 624.
[3] *Ber.*, 1896, **29**, 1762.
[4] Tschitschibabin, *Ber.*, 1904, **37**, 186.
[5] *Ibid.*, 850.
[6] *Compt. Rend.*, 1903, **137**, 60.
[7] *Bull. Soc.*, 1903, **29**, 1049.
[8] Zincke, *Annalen*, 1903, **328**, 261.
[9] Perkin, *J. C. S.*, 1904, **85**, 416.
[10] *Annalen*, 1888, **245**, 160.
[11] *J. C. S.*, 1904, **85**, 654.

Transformations.—1-Methyl-3-ketohexahydrobenzene has been converted into 1-methyl-2-ketohexahydrobenzene [1] by the series of reactions already described.[2]

When 1:5-dimethyl-3-keto-Δ^1-tetrahydrobenzene [3] is heated with an equal weight of ammonium carbonate, a small quantity of a base is formed identical with collidine (2:4:6-trimethylpyridine). The mechanism of this process is the exact reverse of Hantzsch's reaction [4] whereby dihydropyridine, under the influence of hydrochloric acid, yields ketotetrahydrobenzene.

It has been shown by Demjanow and Luschnikow [5] that it is possible to convert a substance containing a tetramethylene ring into one containing a pentamethylene ring (cyclopentanol from tetramethylenemethylamine); and, in continuance of this work, Demjanow [6] has now provided an example of the conversion of a ring containing six carbon atoms into one containing seven. On distilling hexahydrobenzamide with phosphorus pentoxide it yields cyanohexahydrobenzene (1), which on reduction gives the corresponding amine (2). When the hydrochloride of this amine

$$CH_2\begin{array}{c} \diagup CH_2-CH_2 \diagdown \\ (1) \\ \diagdown CH_2-CH_2 \diagup \end{array}CH\,.\,CN \qquad CH_2\begin{array}{c} \diagup CH_2-CH_2 \diagdown \\ (2) \\ \diagdown CH_2-CH_2 \diagup \end{array}CH\,.\,CH_2\,.\,NH_2$$

$$CH_2\begin{array}{l} \diagup CH_2-CH_2-CH\,.\,OH \\ \quad\ (3) \qquad\quad\ | \\ \diagdown CH_2-CH_2-CH_2 \end{array}$$

is acted on with silver nitrite it is converted into an alcohol identical in every respect with suberyl alcohol (3), already described by Markownikoff.[7]

A study of the action of bromine on 3 : 5-dichloro-1 : 1-dimethyl-$\Delta^{2:4}$-dihydrobenzene [8] has shown that the resulting hydro-aromatic bodies very readily lose hydrogen bromide to form aromatic substances, of which the two principal ones are 3 : 5-dichloro-4-bromo-*o*-xylene and 3 : 5-dichloro-6-bromo-*o*-xylene. Since the dichlorodimethyldihydrobenzene, which forms the starting-point of the research, contains the *gem*-dimethyl group, the migration of one of these methyl groups becomes an essential step in the production of an aromatic compound. The reaction has therefore been worked out so as to gain an insight into the course of such changes, more especially as, on account of the symmetry of the molecule, it forms one of the simplest cases in which the wandering of an alkyl group can take place. The reaction is largely influenced by the condition of experiment, but no substance has been encountered in which an alkyl group has wandered into any but an ortho-position.

The Nature of Double Linkings.—Recent experimental work has enriched our knowledge of the behaviour of substances containing double linkings, more especially as regards the property of addition. In the case of a substance containing several double bonds in the molecule, these bonds often do not behave independently of one another. Thiele's theory [9] of partial valencies provides a possible explanation of many such cases. Knoevenagel [10] considers it essential to study the movement of the atoms themselves in the molecule, and assumes that doubly linked carbon atoms are

[1] Wallach, *Annalen*, 1903, **329**, 368.
[2] Reports, 1903, p. 181.
[3] Knoevenagel and Erler, *Ber.*, 1903, **36**, 2129.
[4] *Annalen*, 1882, **215**, 297.
[5] *Cent. Blatt.*, 1903 (1), 828.
[6] *Cent. Blatt.*, 1904 (1), 1214.
[7] *Ber.*, 1893 **26**, R, 813.
[8] Crossley, *J. C. S.*, 1904, **85**, 264.
[9] *Annalen*, 1899, **306**, 87.
[10] *Ber.*, 1903, **36**, 2803.

in a continuous state of oscillatory motion. In the case of a substance such as butadiene, the formation of the dibromide $BrCH_2-CH=CH-CH_2Br$, is explained by supposing the swinging motion of the carbon atoms to be taking place first in one direction and then in the opposite, as indicated in the accompanying diagram (fig. 1).

Continuous motion in one direction only is prevented by the hydrogen atoms attached to the terminal carbon atoms, which come into the plane of rotation. It is quite another matter in the case of benzene, where alternate carbon atoms are supposed to rotate continuously in opposite directions, because none of the valencies which pass into the plane of rotation have hydrogen atoms attached to them; the result is that the double linkings change their position and travel round the ring (fig. 2).

FIG. 1.

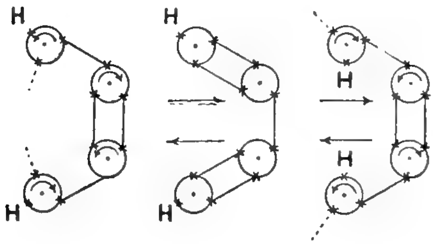
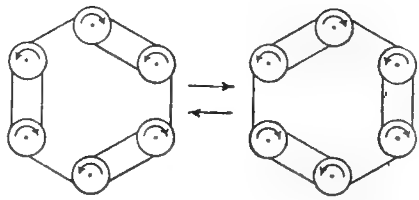
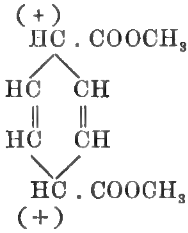


FIG. 2.



Such a theory indicates the possibility of new types of isomerism, more subtle even than optical isomerism, and it is pointed out that cases of supposed polymorphism, *e.g.*, the quinols and benzophenone, may be in reality manifestations of structural differences of the above type. Knoevenagel supports Lehmann's view,[1] that substances exhibiting difference in crystalline form afford evidence of difference in chemical or, perhaps better, physical constitution.

It is also suggested that bodies of the type of ethyl $\Delta^{2:5}$-dihydroterephthalate should be particularly liable to lose a molecule of hydrogen,



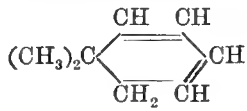
since the two hydrogen atoms marked (+) would be in a continuous state of bombardment, due to the swinging motion of the carbon atoms connected by a double bond. On increasing the temperature this state of things would become sufficiently intense to cause the partial dissociation of the molecule with evolution of hydrogen. This actually happens in the case of the above ethereal salt on heating[2] in an atmosphere of carbon dioxide, especially in presence of platinum black. The evolved hydrogen is much smaller in amount than required by theory, only 18 c.c. being obtained by heating one gram of the salt instead of 113 c.c. This is

[1] *Molekularphysik* (2), 413. [2] *Ber.*, 1903, **36**, 2857.

readily explained, for the evolved hydrogen combines with some unaltered ester, and the result of the reaction is the production of methyl terephthalate and methyl hexahydroterephthalate.

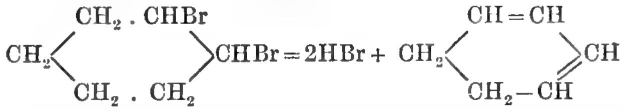
$\Delta^{1:3}$-*Dihydrobenzene.* *By* Dr. A. W. Crossley.

In the last report of this Committee,[1] brief allusion was made to the preparation of $\Delta^{1:3}$-dihydrobenzene; work in this direction has now been completed, with results which entirely confirm the preliminary experiments. The hydrocarbon obtained from dimethyldihydroresorcin by Crossley and Le Sueur[2] was proved to be 1 : 1-dimethyl-$\Delta^{2:4}$ dihydro-



benzene, and by submitting dihydroresorcin to an identical series of reactions a hydrocarbon was obtained,[3] which differed from any previously prepared dihydrobenzene in only combining with one molecule of bromine to give a dibromodihydrobenzene melting at 104°·5. It was therefore suggested that the double bonds would be in the position 1 : 3, and the hydrocarbon prepared by Baeyer[4] and Markownikoff[5] would be $\Delta^{1:4}$-dihydrobenzene, which is characterised by directly adding on four atoms of bromine to form a solid tetrabromide melting at 184°. Harries and Antoni[6] consider that their work proves this suggestion to be incorrect.

Unfortunately it was not found possible to prepare pure $\Delta^{1:3}$-dihydrobenzene from dihydroresorcin, but this end has now been attained by the removal of the elements of hydrogen bromide from dibromotetrahydrobenzene.[7]



The reaction can only take place in one way, and therefore leaves no doubt as to the constitution of the resulting hydrocarbon, which like that obtained from dihydroresorcin only adds on two atoms of bromine to give a solid melting at 104°·5. That this latter substance is in reality a dibromodihydrobenzene is conclusively proved by the fact that on treatment with quinoline it loses two molecules of hydrogen bromide, yielding benzene.

It seems indisputable that, as already suggested, the hydrocarbon obtained from dihydroresorcin or from dibromotetrahydrobenzene is $\Delta^{1:3}$-dihydrobenzene, and the hydrocarbon giving the tetrabromide melting at 184° must therefore be $\Delta^{1:4}$-dihydrobenzene.

[1] Southport, 1903, p. 182.
[2] *J. C. S.*, 1902, **81**, 822.
[3] Crossley and Haas, *J. C. S.*, 1903, **83**, 494.
[4] *Annalen*, 1894, **278**, 88.
[5] *Annalen*, 1898, **302**, 29.
[6] *Annalen*, 1903, **328**, 102.
[7] *Proc. C.S.*, 1904, **20**, 160.

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee consisting of Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Sir NORMAN LOCKYER, Professor J. DEWAR, Professor G. D. LIVEING, Professor A. SCHUSTER, Professor W. N. HARTLEY, Professor WOLCOTT GIBBS, Sir W. DE W. ABNEY, *and* Dr. W. E. ADENEY.

RUTHENIUM.

Kayser, 'Königl. Preuss. Akad. Wissensch. Berlin,' 1897.
Adeney, 'Proc. Royal Dublin Soc.' vol. x. (n.s.), pt. 1, No. 3.
Exner and Haschek, 'Sitzungsber. kais. Akad. Wissensch. Wien,' cv. 1896, cvi. 1897.
Rowland and Tatnall, 'Astro.-phys. Journ.' vol. iii. p. 288, 1896.

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5887·371			0	1·60	4·6	16980·9
64·830			0	,,	,,	17046·2
33·561			0n	1·59	4·7	17137·5
33·380			2	,,	,,	38·0
28·580			1	,,	,,	52·1
28·235			2	,,	,,	53·1
26·018			0	,,	,,	59·5
15·157			5	1·58	,,	91·7
04·461			4	,,	,,	17223·4
5792·382			1	,,	,,	59·3
90·741			1	,,	,,	64·2
82·720			4	,,	,,	88·2
82·511			2	,,	,,	88·8
74·533			2	1·57	,,	17312·7
71·352			0	,,	,,	22·3
68·066			3	,,	,,	32·1
58·875			0	,,	,,	59·8
56·980			3	,,	,,	66·1
53·772			1	,,	,,	75·2
52·163			3	,,	,,	80·0
47·623			5	,,	,,	93·8
46·131			4	,,	,,	98·2
45·776			1	,,	,,	99·4
40·710			0	,,	,,	17414·7
34·606			0	1·56	,,	33·3
30·122			2	,,	,,	46·7
25·895			4	,,	,,	59·8
24·975			4	,,	,,	62·6
14·391			2	,,	4·8	93·9
13·025			4	,,	,,	99·1
02·522			4	1·55	,,	17531·3
5699·741			2	,,	,,	39·9
99·224			9	,,	,,	41·5
96·526			1	,,	,,	49·8
94·626			2	,,	,,	55·6
93·190			4	,,	,,	60·1
92·288			1	,,	,,	62·8
88·990			2	,,	,,	73·0

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5679·790			4	1·55	4·8	17601·5
76·720			1	,,	,,	11·0
65·370			4	1·54	,,	46·3
63·233			0	,,	,,	52·9
57·127			2	,,	,,	72·0
53·482			2	,,	,,	83·4
53·005			0	,,	,,	84·9
50·981			2	,,	,,	91·2
49·737			3	,,	,,	95·1
48·058			1	,,	,,	17700·4
47·755			0	,,	,,	01·3
41·848			2	,,	,,	20·3
36·441			7	,,	,,	36·9
29·984			1	,,	,,	57·2
27·722			2	1·53	,,	64·4
19·558			0	,,	,,	90·2
09·360			2	,,	4·9	17822·4
06·958			3	,,	,,	31·1
03·782			3	,,	,,	36·2
03·370			2	,,	,,	41·5
00·753			2	,,	,,	49·8
5582·501			2	1·52	,,	17908·2
79·650			2	,,	,,	17·4
78·914			2	,,	,,	19·7
78·594			4	,,	,,	20·8
70·906			2	,,	,,	45·5
69·233			4	,,	,,	50·9
59·962			6	,,	,,	80·8
56·719			3	,,	,,	91·3
49·960			2	1·51	,,	18013·2
40·881			3	,,	,,	42·8
31·220			2	,,	,,	74·2
18·056			2	,,	,,	18117·4
12·593			2	1·50	,,	35·4
10·934			6	,,	,,	42·8
07·151			0	,,	,,	53·3
01·230			1	,,	5·0	72·7
5496·899			4	,,	,,	90·4
94·575			1	,,	,,	95·0
84·850			2	,,	,,	18227·0
84·524			6	,,	,,	28·1
80·507			3	,,	,,	41·5
79·619			4	,,	,,	44·3
75·377			2	1·49	,,	58·6
73·050			2	,,	,,	66·3
71·755			0	,,	,,	70·7
56·329			2n	,,	,,	18322·3
55·018			6	,,	,,	26·7
52·930			1	,,	,,	33·8
39·618			2n	1·48	,,	78·6
39·421			2	,,	,,	79·3
27·815			4	,,	,,	18418·6
19·056			4	,,	,,	48·4
01·609			2	1·47	5·1	18507·9
01·234			5	,,	,,	09·2
5386·083			4	,,	,,	61·2

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
5378·042			3	1·47	5·1	18589·0
73·505			0n	,,	,,	18604·7
65·799			2	,,	,,	31·5
62·271			2	1·46	,,	43·7
61·967			5	,,	,,	44·8
48·340			0	,,	,,	92·3
36·110			3	,,	,,	18735·1
34·901			2n	,,	,,	39·4
33·114			3	,,	,,	45·7
15·520			2	1·45	,,	18807·7
09·440			4	,,	,,	29·3
07·481			0	,,	,,	37·2
06·624			1	,,	,,	39·3
06·035			0	,,	,,	41·4
05·030			4	,,	,,	44·9
5291·327			1	,,	5·2	93·6
84·256			4	1·44	,,	18918·9
80·989			2	,,	,,	30·6
75·240			1	,,	,,	51·2
66·988			1	,,	,,	81·0
66·642			1	,,	,,	82·2
64·113			0n	,,	,,	91·3
57·240			2	,,	,,	19016·1
51·816			1	,,	,,	35·8
45·612			2	1·43	,,	58·3
45·112			0	,,	,,	60·2
43·109			2n	,,	,,	67·4
42·560			1	,,	,,	69·4
35·774			1	,,	,,	94·4
23·708			3	,,	,,	19138·1
14·247			1	,,	,,	72·8
13·586			3	,,	,,	75·2
09·667			2	1·42	,,	89·9
02·285			2	,,	5·3	19217·0
00·040			3	,,	,,	25·3
5195·171			4	,,	,,	43·3
76·361			0	,,	,,	19313·3
74·105			0	1·41	,,	21·7
71·193			6	,,	,,	32·5
69·242			0	,,	,,	39·8
68·793			0	,,	,,	41·6
68·237			0	,,	,,	43·6
60·167			2	,,	,,	73·9
55·302			4	,,	,,	92·2
53·364			2	,,	,,	99·5
51·230			4	,,	,,	19407·5
47·401			4	,,	,,	22·0
42·933			4	,,	,,	44·2
36·717			5	1·40	,,	62·4
34·285			0	,,	,,	71·6
34·059			2	,,	,,	72·5
27·423			2	,,	,,	97·7
07·230			4	,,	5·4	19574·7
01·892			0	,,	,,	95·2
01·553			2	,,	,,	96·5
5093·996			4	1·39	,,	19625·6

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
5077·484			3	1·39	5·4	19689·4
77·243			1	,,	,,	90·3
73·141			2	,,	,,	19706·2
62·815			1	1·38	,,	46·5
57·487			4	,,	,,	67·3
53·114			0	,,	,,	84·4
47·471			2	,,	,,	19806·5
45·570			1	,,	,,	14·0
41·528			0	,,	,,	29·9
40·908			1	,,	,,	32·3
40·521			1	,,	,,	33·8
39·794			0n	,,	,,	36·7
26·343			3	1·37	5·5	89·7
20·472			0	,,	,,	19912·9
19·140			1	,,	,,	18·2
11·387			3	,,	,,	49·0
10·765			1	,,	,,	51·5
05·394			1	,,	,,	73·0
03·697			0	,,	,,	79·7
4992·891			2	,,	,,	20023·0
87·412			1	1·36	,,	45·0
80·498			2	,,	,,	72·8
76·351			2	,,	,,	89·5
75·534			0	,,	,,	92·8
74·255			0	,,	,,	98·0
69·055			2	,,	,,	20119·0
60·022			0	,,	,,	56·7
55·416			1	,,	,,	74·4
38·587			3	1·35	5·6	20243·1
35·805			0	,,	,,	54·5
21·233			4	,,	,,	20314·4
11·755			1	1·34	,,	53·7
10·384			0	,,	,,	59·4
08·045			3	,,	,,	69·1
05·179			1	,,	,,	83·0
03·223			5	,,	,,	89·2
02·033			0	,,	,,	94·1
01·234			0	,,	,,	97·4
4899·416			1	,,	,,	20405·0
95·745			4	,,	,,	20·3
95·555			1	,,	,,	21·1
95·474			1	,,	,,	21·4
85·186			0	,,	,,	64·5
82·832			0	,,	,,	81·1
77·598			0	1·33	,,	96·3
75·188			0	,,	,,	20506·4
74·489			0	,,	,,	09·4
69·952			1	,,	,,	28·5
69·314			6	,,	,,	31·2
65·253			1	,,	,,	48·3
63·265			0	,,	,,	56·7
62·024			2	,,	5·7	62·1
54·731			1	,,	,,	92·8
44·720			4	,,	,,	20635·3
39·930			1	1·32	,,	55·8
39·174			3	,,	,,	49·0

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		+ λ	$\frac{1}{\lambda}$ −	
4833·157			2	1·32	5·7	20644·7
28·865			0	,,	,,	20703·1
22·738			0	,,	,,	29·4
17·512			1	,,	,,	51·9
15·694			5	,,	,,	59·7
14·895			0	,,	,,	63·2
13·412			0	,,	,,	70·6
06·375			0	,,	,,	20800·0
05·043			2	,,	,,	05·8
01·343			1	1·31	,,	21·8
4798·607			2	,,	,,	33·7
95·721			2	,,	,,	46·3
94·547			2	,,	,,	51·3
81·937			1	,,	5·8	20906·3
74·168			0	,,	,,	40·2
73·325			0	,,	,,	43·9
69·464			4	,,	,,	61·2
67·315			0	,,	,,	70·4
64·582			0	1·30	,,	72·4
58·043			6	,,	,,	21011·2
56·402			2	,,	,,	18·5
53·280			0	,,	,,	32·2
51·197			0	,,	,,	41·5
43·205			1	,,	,,	77·0
38·587			0	,,	,,	97·5
33·710			4	,,	,,	21119·3
33·486			0	,,	,,	20·3
31·504			3	,,	,,	29·1
21·078			1	1·29	,,	75·8
18·228			0	,,	,,	88·6
16·201			2	,,	,,	97·5
14·335			0	,,	,,	21206·1
12·146			1	,,	,,	15·9
09·672		4709·55	6	,,	,,	27·1
		04·2	1	,,	,,	
		02·6	1	,,	,,	
		4692·3	1	1·28	,,	
4690·284		90·5	4	,,	5·9	21314·7
		87·3	1	,,	,,	
85·947		86·2	1	,,	,,	34·5
84·196		84·4	4	,,	,,	42·4
83·258			0	,,	,,	46·7
81·966		82·2	4	,,	,,	52·6
81·563			0	,,	,,	54·5
		77·5	1n	,,	,,	
74·821		75·0	4	,,	,,	85·3
		74·0	1n	,,	,,	
70·146		70·4	4	,,	,,	21407·0
		69·5	1	,,	,,	
		68·5	1n	,,	,,	
		67·5	1n	,,	,,	
62·663			0	,,	,,	41·1
54·901			0	1·27	,,	76·8
54·489		54·6	4	,,	,,	78·7
52·371			0	,,	,,	88·5
48·293			0	,,	,,	21507·4

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4647·787		4647·68	5	1·27	5·9	21509·7
46·967			0	,,	,,	14·9
46·326			0	,,	,,	16·5
45·264		45·4	4	,,	,,	21·4
42·752			1	,,	,,	33·1
42·548			1	,,	,,	34·1
41·135		41·2	0	,,	,,	40·5
39·490		39·1	0	,,	,,	48·2
38·569			0	,,	,,	52·5
35·849		36·0	4	,,	,,	65·1
28·495			0	,,	6·0	98·8
26·184			1	,,	,,	21610·1
17·827			0	1·26	,,	49·2
		12·5	1	,,	,,	
		10·6	1n	,,	,,	
		09·5	1n	,,	,,	
05·833		05·8	2	,,	,,	21705·6
02·978			0	,,	,,	20·1
01·933		01·9	3	,,	,,	26·8
*4599·271		4599·30	6	,,	,,	36·6
96·879		97·1	4	,,	,,	47·9
93·367			0	,,	,,	64·5
93·161			0	,,	,,	65·4
* 92·695		92·7	4	,,	,,	67·7
91·717			2	,,	,,	72·3
* 91·257		91·4	4	,,	,,	74·5
89·734			0	,,	,,	81·8
89·177		87·4	0	,,	,,	84·4
		85·5	1	,,	,,	
* 84·632		84·60	4	,,	,,	21806·0
		81·5	1n	,,	,,	
80·246		80·4	3	1·25	,,	26·4
		74·2	1n	,,	,,	
64·862		65·0	2	,,	6·1	21900·4
62·772		62·9	1	,,	,,	10·4
* 60·157	4560·16	60·3	4	,,	,,	22·9
59·215			1	,,	,,	27·5
		56·5	1n	,,	,,	
* 54·696	54·70	54·71	6r	,,	,,	49·3
* 52·281	52·28	52·5 Pt	4	,,	,,	60·9
* 50·112	50·11	50·3	3	,,	,,	71·4
49·589		49·6	2	,,	,,	73·9
* 48·030	48·03	48·2	4	,,	,,	81·4
* 47·463	47·46	47.6	4	,,	,,	84·2
47·105		47·3	2	,,	,,	85·9
		45·4	1n	,,	,,	
		44·0	1	,,	,,	
42·848	42·85	42·7	1	1·24	,,	22013·1
		42·0	1n	,,	,,	
		41·4	1n	,,	,,	
	40·05	40·2	1n	,,	,,	20·1
		36·0	1n	,,	,,	
		35·0	1n	,,	,,	

* Rowland and Tatnall: 4599·265, 4592·699, 4591·285, 4584·619, 4560·168, 4554·697, 4552·293, 4550·121, 4548·031, 4547·467.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	1/λ −	
4531·035	4531·04	4531·2	4	1·24	6·1	22063·9
25·616			0	,,	,,	90·3
* 21·110	21·11	21·3	4	,,	,,	22112·4
* 17·977	17·98	18·2	4	,,	,,	27·7
* 17·060	17·06	17·3	4	,,	,,	32·2
16·421	16·42	16·6	2	,,	,,	35·3
* 11·353	11·35	11·5	4	,,	,,	60·2
* 10·251	10·25	10·4	4	,,	,,	65·6
08·715	08·72	08·8	2	,,	,,	73·2
08·192		08·3	1	,,	,,	75·7
*4498·322	4498·32	4498·30	4	1·23	,,	22219·4
91·846	91·85	92·1	2	,,	6·2	56·4
90·396	90·40	90·5	2	,,	,,	63·5
88·550	88·50	88·7	4	,,	,,	72·7
82·194	82·19	82·3	2	,,	,,	22304·3
* 80·603	80·60	80·7	4	,,	,,	12·2
	79·80	79·7	1	,,	,,	16·3
75·493		75·7	2	,,	,,	37·7
* 74·093	74·09	74·2	4	,,	,,	44·7
71·200			0	,,	,,	59·2
	70·69	70·8	1	,,	,,	61·7
67·427		67·6	2	1·22	,,	78·0
66·511			2	,,	,,	82·7
65·649	65·65		1	,,	,,	87·0
64·661	64·66		0	,,	,,	91·9
* 60·209	60·21	60·19	6	,,	,,	22414·3
		53·5	1n	,,	,,	
* 49·509	49·51	49·50	4	,,	,,	68·2
* 44·674	44·67	44·8	4	,,	,,	92·6
		43·3	1n	,,	,,	
40·245			0	,,	,,	22509·1
* 39·938	39·94	39·98	5	,,	,,	16·6
39·574			2	,,	,,	18·5
		38·6	1	,,	,,	
30·478			1	1·21	6·3	64·6
* 28·624		28·65	4	,,	,,	74·1
26·182	26·18		1	,,	,,	86·5
24·958		25·2	3	,,	,,	92·8
23·143		23·3	1	,,	,,	22602·0
* 21·629	21·63	21·7	4	,,	,,	09·8
21·006	21·01	21·2	4	,,	,,	13·0
20·634	20·63		2	,,	,,	14·9
14·607			2	,,	,,	45·7
13·458			2	,,	,,	51·6
12·058			0	,,	,,	58·8
* 10·207	10·21	10·17	6	,,	,,	68·4
		09·1	1n	,,	,,	
05·809		05·2	0	,,	,,	91·0
		02·7	1n	,,	,,	
4399·751	99·75	00·0	1	,,	,,	22722·3
* 97·956	97·96	4398·3	4	,,	,,	31·5
96·868			0	,,	,,	37·2

* Rowland and Tatnall: 4521·124, 4517·985, 4517·063, 4511·364, 4510·265, 4498·316, 4480·617, 4474·100, 4460·194, 4449·509, 4444·681, 4439·935, 4428·631, 4421·626, 4410·193, 4397·966.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4395·125	4495·13	4395·4	2	1·21	6·3	22746·1
* 91·191	91·19	91·5	4	1·20	,,	66·5
* 90·614	90·61	90·60	6	,,	,,	69·6
89·547		89·4	0	,,	,,	75·1
89·150			2	,,	,,	77·1.
* 86·431	4386·43	86·6	4	,,	,,	91·3
		86·1	4	,,	,,	
* 85·823	85·82	85·85	5	,,	,,	94·4
* 85·563	85·56	85·60	5	,,	,,	95·8
* 83·530	83·53	83·7	2	,,	,,	22806·4
81·421	81·42	81·7	2	,,	,,	17·3
76·745		76·8	1	,,	,,	41·7
		73·9	1	,,	,,	
		73·4	1	,,	,,	
* 72·381	72·38	72·38	5	,,	,,	64·5
	71·52	71·6	2	,,	,,	68·8
* 71·363			4	,,	,,	69·9
70·580		70·9	2	,,	,,	74·0
65·741			0	,,	6·4	99·2
64·270		64·6	2	,,	,,	22906·9
		63·5	1	,,	,,	
62·872		63·2	1	,,	,,	20·3
* 61·581			2	,,	,,	21·0
* 61·372	61·37	61·40	5	,,	,,	22·1
		58·5	1n	,,	,,	
57·031		57·6	1	,,	,,	45·0
* 54·960	54·96	55·2	3	1·19	,,	55·9
* 54·300	54·30	54·32	6	,,	,,	59·4
50·632			0	,,	,,	78·8
* 49·868	49·86	49·90	5	,,	,,	82·8
* 46·640		46·9	4	,,	,,	99·9
43·178		43·7	0	,,	,,	23018·2
* 42·243	42·24	42·25	6	,,	,,	23·2
41·204		41·4	2	,,	,,	28·6
40·503		40·7	2	,,	,,	32·4
		40·0	1n	,,	,,	
38·829		39·1	2	,,	,,	41·3
* 37·427	37·43	37·6	4	,,	,,	48·7
		37·3	1	,,	,,	
* 36·584	36·58	36·7	2	,,	,,	53·2
		33·1	1	,,	,,	
32·789		32·9	0	,,	,,	73·4
32·655	32·66		2	,,	,,	74·1
* 31·321	31·32	31·5	4	,,	,,	81·8
28·712		29·0	2	,,	,,	95·2
* 27·588	27·59	27·8	3	,,	,,	23101·2
27·489			2	,,	,,	01·7
* 26·987	26·99	27·2 Pt	4	,,	,,	04·4
* 25·215	25·22	25·4	4	,,	,,	13·8
23·626			0	,,	,,	22·3
23·120	23·15	23·3	2	,,	,,	25·0
21·450			2	,,	,,	34·0

* Rowland and Tatnall: 4391·191, 4390·605, 4386·436, 4385·814, 4385·553, 4383·526, 4372·363, 4371·366, 4361·597, 4361·371, 4354·969, 4354·296, 4349·867, 4346·645, 4342·236, 4337·431, 4336·591, 4331·329, 4327·590, 4326·986, 4325·213.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	1/λ −	
4320·972		4321·0	0	1·19	6·4	23137·5
20·743			2	,,	,,	37·8
* 20·045	4320·04	20·08	5	,,	,,	41·4
19·274			2	,,	,,	45·6
* 18·596	18·60	18·7	4	1·18	,,	49·3
* 16·792		17·0	2	,,	,,	59·0
15·219			4	,,	,,	67·4
* 14·468	14·47	14·6	4	,,	,,	71·4
13·067			0	,,	,,	79·0
12·632		12·8	2	,,	,,	81·3
12·047			0	,,	,,	84·4
		11·0	1	,,	,,	
09·361		09·6	2	,,	,,	98·9
08·567	08·57		0	,,	6·5	23203·1
* 07·748	07·75	07·74	4	,,	,,	07·5
		06·2	1	,,	,,	
		05·0	1	,,	,,	
02·150			0	,,	,,	37·7
01·297		01·5	1	,,	,,	42·3
		4299·3	1	,,	,,	
*4297·887	4297·89	97·92	8	,,	,,	60·8
96·860	96·86	97·1	2	,,	,,	66·3
* 96·090	96·09	96·05	5	,,	,,	70·4
* 94·955	94·96	94·95	5	,,	,,	76·6
94·268			4	,,	,,	80·3
* 93·441	93·44	93·48	4	,,	,,	84·8
92·419		92·6	0	,,	,,	90·4
90·692	90·69	90·9	2	,,	,,	99·8
* 87·209	87·21	87·4	4	,,	,,	23318·7
* 84·502	84·49	84·50	6	,,	,,	33·4
		83·4	1n	,,	,,	
* 82·357	82·36	82·6	2	,,	,,	35·1
* 82·093	82·09	82·3	2	,,	,,	46·6
		81·7	1	,,	,,	
		79·6	1	1·17	,,	
* 78·842			2	,,	,,	64·0
* 77·415		77·6	2	,,	,,	72·1
73·115			0	,,	,,	95·6
		72·0	1n	,,	,,	
		67·0	0	,,	,,	
66·157				,,	,,	23433·8
* 65·766	65·77	65·9	2	,,	,,	37·0
63·551		63·7	2	,,	,,	48·1
60·166	60·17	60·3	3	,,	,,	66·7
* 59·152	59·15	59·20	5	,,	,,	72·3
		57·6		,,	,,	
56·790		57·0	0	,,	,,	85·4
56·049		56·1	0	,,	,,	89·5
55·868		55·7	1	,,	,,	90·5
48·304		48·5	2	,,	6·6	23532·2
* 46·902	46·90	46·95	4	,,	,,	40·0
* 46·522	46·52	46·55	4	,,	,,	42·1

* Rowland and Tatnall: 4320·036, 4318·599, 4316·801, 4314·471, 4307·746, 4297·870, 4296·090, 4294·948, 4293·443, 4287·204, 4284·490, 4282·367, 4282·089, 4278·844, 4277·413, 4265·762, 4259·144, 4246·893, 4246·498.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
4246·359			6	1·17	6·6	23543·0
* 44·997	4245·05	4245·2	4	,,	,,	50·5
* 43·228	43·23	43·20	6	1·16	,,	60·3
* 41·231	41·23	41·25	6	,,	,,	71·4
40·194		40·4	0	,,	,,	76·9
		40·0	1	,,	,,	
		38·5	1n	,,	,,	
* 36·838	36·84	37·1	4	,,	,,	23604·0
		33·6	1	,,	,,	
* 32·478	32·48	32·6	4	,,	,,	20·2
		31·7	1	,,	,,	
* 30·470	30·20	30·48	6	,,	,,	31·4
* 29·472	29·47	29·6	4	,,	,,	37·1
		28·2	1	,,	,,	
* 26·825	26·82	27·0 Ca	0	,,	,,	
* 25·258	25·26	25·4	3	,,	,,	60·6
* 20·838	20·84	20·85	4	,,	,,	85·4
* 17·438	17·44	17·40	7	,,	,,	23705·5
* 14·610	14·61	14·60	4	,,	,,	20·4
		13·8	1	,,	,,	
* 12·240	12·24	12·20	5	,,	,,	33·7
		09·5	1	,,	,,	
* 07·797	07·80	08·0	2	,,	,,	58·8
* 06·178	06·18	06·20	4	,,	,,	67·9
		03·5	1	1·15	,,	
		03·2	1	,,	,,	
* 00·069	00·07	00·05	7	,,	6·7	23802·5
*4199·039	4199·04	4199·02	4	,,	,,	08·2
* 97·748	97·75	97·78	4	,,	,,	15·6
* 97·038	97·04	97·05	2	,,	,,	19·6
		95·0	1	,,	,,	
* 89·639		89·9	0	,,	,,	61·7
		88·6	1n	,,	,,	
		84·5	1n	,,	,,	
* 82·994		83·0	0	,,	,,	99·6
* 82·807			1	,,	,,	23900·7
* 82·621	82·62	82·8	2	,,	,,	01·7
* 75·615		75·8 Os	2	,,	,,	41·9
		75·3	2	,,	,,	
		74·5	1n	,,	,,	
		73·4	1	,,	,,	
		70·9	1n	,,	,,	
* 70·218	70·22	70·5	2	,,	,,	72·8
		69·3	1	,,	,,	
* 67·666	67·67	67·65	5	1·14	,,	87·5
* 67·030	67·03	67·3	0	,,	,,	91·2
		65·1	1n	,,	,,	
		64·8	1n	,,	,,	
* 61·817	61·82	61·80	4	,,	,,	24021·3
		59·5	1	,,	,,	
		58·2	1	,,	,,	

* Rowland and Tatnall: 4244·992, 4243·216, 4241·215, 4236·834, 4232·481, 4230·478, 4229·475, 4226·824, 4225·256, 4220·838, 4217·427, 4214·714, 4214·604, 4212·225, 4207·798, 4206·178, 4200·062, 4199·039, 4197·745, 4197·039, 4189·631, 4182·998, 4182·812, 4182·623, 4175·604, 4170·219, 4167·683, 4167·047, 4161·823.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
*4150·475	4150·48	4150·6	1	1·14	6·7	24086·9
* 48·530	48·53	48·7	1	,,	6·8	98·1
* 46·956	46·96	46·92	4	,,	,,	24107·3
* 45·905	45·80	45·95	4	,,	,,	13·4
* 44·335		44·35	4	,,	,,	24·4
38·923			0	,,	,,	54·1
* 37·410	37·41	37·6	3	,,	,,	62·9
		35·8 Os	1	,,	,,	
		35·2	1	,,	,,	
		31·7	1n	,,	,,	
		29·2	1n	1·13	,,	
* 28·017	28·02	28·2	2	,,	,,	24217·9
* 27·611	27·61	27·7	2	,,	,,	20·3
		26·7	1n	,,	,,	
		25·3	1n	,,	,,	
		24·2	1	,,	,,	
* 23·227	23·23	23·4	2	,,	,,	40·0
21·287		21·4	2	,,	,,	57·4
* 21·147	21·15		2	,,	,,	58·3
* 18·678			2	,,	,,	72·8
14·285		14·5	1	,,	,,	98·8
* 13·532	13·53	13·7	2	,,	,,	24303·2
* 12·910	12·90	12·95	4	,,	,,	06·9
09·796		10·0	0	,,	,,	25·3
* 08·218			2	,,	,,	34·6
* 08·003	08·00	08·2	4	,,	,,	35·9
06·065		06·3	0	,,	,,	47·4
* 02·438		02·6	2	,,	,,	68·9
01·906	01·91	02·1	4	,,	,,	72·1
* 00·533	00·53	00·6	2	,,	,,	80·2
*4097·965	4097·97	4098·00	4	,,	6·9	95·6
* 97·185	97·97	97·5	2	,,	,,	24400·1
		95·3	1n	,,	,,	
* 91·218	91·22	91·5	1	1·12	,,	35·7
		88·7	1	,,	,,	
* 85·567	85·57	85·62	5	,,	,,	69·5
		83·9	1	,,	,,	
82·947		83·2	2	,,	,,	85·2
* 80·777	80·78	80·76	7	,,	,,	98·3
79·440		79·6	1	,,	,,	24506·3
		78·2	1	,,	,,	
* 76·900	76·90	76·90	5	,,	,,	21·5
		74·4	1	,,	,,	
73·260		73·4	2	,,	,,	43·4
* 73·147	73·15		2	,,	,,	44·1
* 71·560		71·8	3	,,	,,	53·7
* 68·529	68·53	68·58	4	,,	,,	72·0
* 67·777	67·78	68·0	4	,,	,,	76·6
* 64·616	64·61	64·9	4	,,	,,	95·7
* 64·262	64·26	64·5	2	,,	,,	97·8
* 63·160	63·16	63·3	2	,,	,,	24604·5

* Rowland and Tatnall: 4150·470, 4148·539, 4146·939, 4145·905, 4144·324, 4137·394, 4128·035, 4127·609, 4123·227, 4121·153, 4118·666, 4113·542, 4112·905, 4108·224, 4108·001, 4102·443, 4100·530, 4097·948, 4097·185, 4091·223, 4085·589, 4080·757, 4076·886, 4073·156, 4071·561, 4068·529, 4067·771, 4064·615, 4064·263, 4063·147.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*4063·021			1	1·12	6·9	24605·3
		4060·7	1n	,,	,,	
		58·2	1n	,,	,,	
* 54·216	4054·22	54·18	4	1·11	,,	58·8
* 52·356	52·36	52·6	4	,,	,,	70·1
* 51·566	51·57	51·56	4	,,	,,	74·9
* 49·570	49·57	49·8	2	,,	7·0	87·0
		47·4	1n	,,	,,	
* —		46·2	2	,,	,,	
		43·5	2n	,,	,,	
42·123			2	,,	,,	24732·5
40·620		40·7	2	,,	,,	41·7
* 39·379	39·37	39·6	4	,,	,,	49·3
37·892		38·2	2	,,	,,	58·4
36·612		37·0	2	,,	,,	66·2
32·650		32·8	1n	,,	,,	90·5
* 32·363	32·36	32·6	4	,,	,,	92·3
* 31·147	31·15	31·4	3	,,	,,	99·8
		30·6	1n	,,	,,	
28·584		28·8	2	,,	,,	24815·8
26·650		27·0	1	,,	,,	27·5
* 24·848		25·1	2	,,	,,	38·3
24·449		24·7	2	,,	,,	41·1
* 24·001	24·00	24·00	4	,,	,,	43·9
22·837		23·1	2	,,	,,	51·1
* 22·327	22·33	22·30	5	,,	,,	54·2
21·146	21·15	21·4	3	,,	,,	61·0
19·699	19·70	19·9 Ir	2	,,	,,	70·5
18·891			1	,,	,,	75·5
		15·8	1n	1·10	,,	
14·297	14·30	14·6	2	,,	,,	24904·0
13·871	13·87	14·1	2	,,	,,	06·6
* 13·655	13·66	13·8	4	,,	,,	07·9
11·882	09·91	11·6	2	,,	,,	19·0
		10·3	1	,,	,,	
* 08·422	08·42	08·6	2	,,	,,	41·5
* 07·680	07·68	07·8	3	,,	,,	45·1
* 06·749	06·75	07·0	4	,,	,,	50·9
* 05·789	05·79	06·0	4	,,	,,	56·9
		04·7	1n	,,	,,	
	03·15	03·3	1n	,,	7·1	73·2
		01·8	1	,,	,,	
		3998·2	1n	,,	,,	
*3996·650	3996·65	96·6	2	,,	,,	25013·9
96·136	96·14	96·10	4	,,	,,	17·1
94·700			1	,,	,,	26·1
89·344			2	,,	,,	59·7
* 87·959	87·96	87·95	4	,,	,,	68·4
* 85·011	85·01	85·00	5	,,	,,	86·3
84·840			1	,,	,,	88·0
82·372	82·37	82·1	3	,,	,,	25103·5
* 79·591	79·59	79·58	2	,,	,,	21·1

* Rowland and Tatnall: 4063·023, 4054·212, 4052·354, 4051·561, 4049·570, 4045·949, 4039·365, 4032·362, 4031·155, 4024·847, 4023·986, 4022·315, 4013·652, 4008·418, 4007·686, 4006·748, 4005·793, 3996·128, 3987·942, 3985·007, 3979·571.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ+	$\frac{1}{\lambda}$−	
*3978·620	3978·62	3978·61	4	1·10	7·1	25127·3
* 74·646	74·65	74·7	5	1·09	,,	52·3
72·568			4	,,	,,	65·5
		70·0	1	,,	,,	
69·936	69·94		0	,,	,,	85·8
	68·64 Ca	68·6 Ca	2	,,	,,	
* 65·057	65·06	65·05	2	,,	,,	25213·2
	61·84	62·3		,,	,,	33·7
* 57·596	57·60	57·7	4	,,	,,	60·8
57·376		57·5	2	,,	,,	62·2
* 52·850	52·85	52·9	0	,,	,,	91·1
52·436			1	,,	7·2	93·6
* 51·351	51·35	51·4	4	,,	,,	25300·7
* 50·548		50·5	3	,,	,,	05·3
* 50·366	50·37	50·4	4	,,	,,	06·9
* 50·192		50·3	2	,,	,,	08·0
* 49·564	49·56	49·6	2	,,	,,	12·1
* 46·456		46·5	2	,,	,,	32·0
* 45·723	45·72	45·73	0	,,	,,	36·7
* 44·341	44·34	44·4	2	,,	,,	45·6
		43·2	1n	,,	,,	
* 42·209	42·21	42·3	4	,,	,,	59·3
* 41·811	41·81	42·0	3	,,	,,	61·8
39·268	39·27		0	,,	,,	78·2
* 38·045	38·05	38·2	3	,,	,,	86·1
34·352			1	,,	,,	25409·9
*	33·80 Ca	33·80 Ca	4	1·08	,,	
	33·06	33·1	1	,,	,,	18·3
32·444			0	,,	,,	22·2
* 31·936	31·94	31·93	4	,,	,,	27·6
26·581			0	,,	,,	60·2
* 26·071	26·07	26·05	6	,,	,,	63·5
* 24·776	24·78	24·9	2	,,	,,	72·0
* 23·636	23·64	23·62	6	,,	,,	79·4
22·476		22·5	1	,,	,,	86·9
21·061	21·06	21·1	4	,,	,,	97·1
*						
19·711			0	,,	,,	25504·9
		16·7	1n	,,	,,	
* 15·000	15·00	15·1	4	,,	,,	35·6
		14·5		,,	,,	
* 12·248	12·25	12·3	3	,,	,,	53·5
11·279		11·4	3	,,	,,	59·9
* 09·229	09·23	09·22	5	,,	,,	73·3
* 08·907	08·91	09·0	3	,,	7·3	75·3
		06·9	1n	,,	,,	
		06·7	1n	,,	,,	
06·141		06·3	1	,,	,,	93·4
		02·4	1	,,	,,	
* 01·393	01·39	01·5	1n	,,	,,	25624·6
		3898·9 Pt	4	,,	,,	

* Rowland and Tatnall: 3978·600, 3974·650, 3965·055, 3957·600, 3952·844, 3951·360, 3950·556, 3950·371, 3950·183, 3949·560, 3946·468, 3945·730, 3944·339, 3942·215, 3941·819, 3938·060, 3933·700, 3931·920, 3926·062, 3924·774, 3923·615, 3920·060, 3914·990, 3912·252, 3909·222, 3908·906, 3901·391.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
*3898·500	3898·50	3898·6	1n	1·08	7·3	25643·5
* 97·390	97·39	97·5	3	,,	,,	50·9
		96·0	2	,,	,,	
		95·1	1n	1·07	,,	
94·387	94·39	94·5	1n	,,	,,	70·6
* 92·916	92·92	93·0	2	,,	,,	80·4
* 92·366	92·37	92·35	2	,,	,,	83·9
* 91·567	91·57	91·6	4	,,	,,	89·3
* 90·350	90·35	90·4	2	,,	,,	97·3
		89·6	4	,,	,,	
* 87·962	87·96	88·0	1	,,	,,	25713·1
		87·6	2	,,	,,	
		86·5	1	,,	,,	
* 84·849	84·85	84·9	1	,,	,,	33·7
* 84·203	84·20	84·3	2	,,	,,	37·9
		82·3	2	,,	,,	
	80·95	81·0	1	,,	,,	59·6
		80·2	1n	,,	,,	
	79·15	79·2	2	,,	,,	71·1
*	76·23	76·2	1	,,	,,	90·0
*	73·65	73·6	1	,,	,,	25808·1
72·386			1	,,	,,	16·2
		71·4	1	,,	,,	
		71·0	1	,,	,,	
		70·8	1	,,	,,	
* 67·965	67·97	67·95	3	,,	,,	46·2
*	65·55	65·6	2	,,	,,	62·2
		63·8	1n	,,	,,	
*	62·82	62·80	6	,,	,,	80·5
		62·0	1	,,	,,	
		60·8	2	,,	,,	
		60·0 Fe	1	,,	,,	
		59·8	1	,,	,,	
		58·8	1	,,	,,	
* 57·689	57·69	57·65	5	,,	,,	25915·0
		57·2	1	,,	,,	
		56·6	2	1·06	,,	
		54·9	1	,,	,,	
		53·4	1n	,,	,,	
*	52·26	52·3	2	,,	,,	51·4
		51·3	1	,,	,,	
*	50·56	50·50	4	,,	,,	62·9
		49·6	1	,,	,,	
		49·1	1	,,	,,	
		48·2	1	,,	,,	
		46·7	2	,,	,,	
		43·2	1	,,	,,	
		42·8	1	,,	,,	
		42·6	1	,,	,,	
		41·1	2	,,	,,	
		40·9	2	,,	,,	
* 39·815	39·82	39·82	4	,,	,,	26035·6
		38·8	2	,,	,,	

* Rowland and Tatnall: 3898·498, 3897·383, 3892·915, 3892·364, 3891·564, 3890·347, 3887·960, 3884·849, 3884·207, 3876·229, 3873·660, 3867·962, 3865·547, 3862·819, 3857·680, 3852·260, 3850·561, 3839·832.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ+	$\frac{1}{\lambda}-$	
*3838·215	3838·22	3838·2	1	1·06	7·3	26046·5
		36·8	1	,,	,,	
		36·1	1	,,	,,	
*	35·19	35·2	2	,,	,,	67·0
		32·3 Pd	1	,,	,,	
* 31·946	31·95	31·82	4	,,	,,	89·1
		31·0	1	,,	,,	
		30·4	1	,,	,,	
		29·5	1	,,	,,	
* 28·859	28·86	28·8	2	,,	,,	26110·1
*		28·0 Fe	1	,,	,,	
		27·5	1	,,	,,	
		26·3	1	,,	,,	
* 25·075	25·08	25·05	1	,,	,,	35·9
		24·5 Fe	1	,,	,,	
* 22·225	22·23	22·19	4	,,	,,	55·3
	20·50	20·5 Fe	1	,,	,,	
	20·00	19·8	1	,,	,,	70·7
* 19·184	19·18	19·2	2	,,	,,	76·3
		18·5 Rh	1	,,	,,	
		18·1	1	,,	,,	
* 17·439	17·44	17·43	3	,,	,,	87·9
		16·9	1	1·05	7·4	
	16·4	16·3	1	,,	,,	95·4
	15·90	16·0 Fe	1	,,	,,	98·7
*	15·0	15·0	2	,,	,,	26204·9
		14·1	1	,,	,,	
	13·20	13·2	1	,,	,,	17·3
* 12·874	12·87	12·83	3	,,	,,	27·3
		12·0	1	,,	,,	
		11·3	1	,,	,,	
*	08·82	08·7	2	,,	,,	47·4
		06·7	1	,,	,,	
*	05·57	05·5	2	,,	,,	69·9
	04·70			,,	,,	
	04·20			,,	,,	
*	03·40	03·4	2	,,	,,	85·3
		01·4	1	,,	,,	
*	00·39	00·38 Ir	4	,,	,,	
*3799·486	3799·49	3799·42	4r	,,	,,	26311·9
* 99·040	99·04	99·05	4	,,	,,	15·0
* 98·205	98·21	98·18	1	,,	,,	20·8
* 95·327	95·33	95·3	0	,,	,,	40·7
*	95·00	95·0	2	,,	,,	43·1
		93·3 Rh	1	,,	,,	
* 90·649	90·65	90·62	5	,,	,,	73·3
		89·8	1	,,	,,	
		88·8	1	,,	,,	
		88·0 Fe	1	,,	,,	
* 86·193	86·19	86·27	5	,,	,,	26404·4
	84·30	84·4	1	,,	,,	17·3
		83·5	1	,,	,,	

* Rowland and Tatnall: 3838·201, 3835·191, 3831·934, 3828·849, 3828·319, 3825·074, 3822·233, 3819·173, 3817·424, 3814·976, 3812·869, 3808·824, 3805·570, 3803·326, 3800·393, 3799·489, 3799·042, 3798·189, 3795·316, 3795·052, 3790·655, 3786·194.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3782·891	3782·89	3782·8	0	1·05	7·4	26434·3
81·313	81·31	81·25	3	,,	,,	38·4
	80·20	80·1	1	,,	,,	46·2
*	78·90	78·9	2	,,	,,	55·3
	78·00	78·0	2n	,,	,,	61·6
* 77·723	77·72	77·78	3	,,	,,	63·6
		74·6	1	1·04	,,	
* 73·306	73·31	73·4	0	,,	,,	94·5
71·244		71·3	0	,,	7·5	26509·0
		70·0	1n	,,	,,	
		69·3	1	,,	,,	
* 67·500	67·50	67·50	4	,,	,,	35·3
65·938		66·0	0	,,	,,	46·3
* 64·179	64·18	64·3	1	,,	,,	58·7
	64·00	64·0 Fe	1	,,	,,	
		62·7	1	,,	,,	
* 61·644	61·64	61·70	4	,,	,,	76·6
* 60·178	60·18	60·15	4	,,	,,	87·5
* 59·976	59·98	60·00	2	,,	,,	89·4
	58·50	58·5	1	,,	,,	98·9
	57·80	57·8	1	,,	,,	26603·8
	57·40	57·4	1n	,,	,,	06·6
* 56·083	56·08	56·07	4	,,	,,	16·0
* 55·865			2	,,	,,	18·6
* 55·241	55·24	55·2	3	,,	,,	21·9
* 53·695	53·70	53·70	4	,,	,,	32·9
	53·00	53·0	1	,,	,,	37·8
	52·70			,,	,,	
	52·00	52·0	1	,,	,,	45·0
	50·60	50·6	1	,,	,,	54·9
	49·60			,,	,,	
	48·40			,,	,,	
	48·15			,,	,,	
	47·15	47·1	1	,,	,,	79·4
46·372		46·4	2	,,	,,	85·0
	46·00			,,	,,	
	45·75	45·72	6	,,	,,	89·4
44·550	44·55	44·55	2	,,	,,	97·9
* 44·367	44·37	44·35	2	,,	,,	99·2
	43·45	43·5	1	,,	,,	26703·8
* 42·938	42·94	42·95	4	,,	,,	09·5
* 42·435	42·44	42·45	5	,,	,,	13·0
		40·5	1	,,	,,	
* 39·622	39·62	39·60	4	,,	,,	33·2
* 39·058	39·06	39·1	2	,,	,,	37·2
* 38·774	38·77	38·8 Pd	2	,,	,,	39·2
* 37·904	37·90		2	1·03	,,	51·6
* 37·548	37·55	37·5	3	,,	,,	48·0
	35·00 Fe	35·0	2	,,	,,	66·3
	34·70	34·6	2	,,	,,	68·4
	33·90	34·0	1n	,,	,,	74·1
* 33·187		33·3	2	,,	,,	79·2

* Rowland and Tatnall: 3778·853, 3777·729, 3773·314, 3767·495, 3764·173, 3761·655, 3760·163, 3759·979, 3756·075, 3755·868, 3755·234, 3753·684, 3744·363, 3742·933, 3742·422, 3739·610, 3739·057, 3738·773, 3737·902, 3737·540, 3733·188.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
*3732·170	3732·17		2	1·03	7·5	26786·5
* 31·045		3731·0	2	,,	,,	94·6
* 30·745		30·65	3	,,	,,	26803·6
* 30·587	30·59		7	,,	7·6	04·6
* 28·170	28·17	28·15	5	,,	,,	15·3
	27·33					
* 27·077	27·08	27·15	4	,,	,,	23·1
* 26·254	26·25	26·10	4	,,	,,	29·0
	25·59	25·6 Ir	1	,,	,,	
* 25·115	25·12	25·1	4	,,	,,	37·2
24·663			2	,,	,,	40·5
24·110	24·11	24·2	4	,,	,,	44·5
	22·80	22·9	1	,,	,,	53·9
22·458		22·3	1	,,	,,	56·4
* 19·474	19·47	19·52	4	,,	,,	75·9
	18·60	18·5	1	,,	,,	84·2
* 17·823	17·82	17·8	2	,,	,,	89·9
* 17·152	17·15	17·13	4	,,	,,	94·6
16·583			1	,,	,,	26901·6
* 16·323	16·32	16·4	3	,,	,,	00·7
* 15·703	15·70	15·7	3	,,	,,	07·2
14·788		15·0	1	,,	,,	11·6
		13·6	1	,,	,,	
* 12·443	12·44	12·5	3	,,	,,	28·8
		11·2	1	,,	,,	
		10·5	1	,,	,,	
	09·35	09·4	1	,,	,,	51·2
	08·15	08·2	1	,,	,,	58·0
	07·05			,,	,,	
* 05·506	05·51	05·5	2	,,	,,	79·2
* 03·344	03·34	03·4	2	,,	,,	95·0
		03·1	1	,,	,,	
* 02·369	02·37	02·5	2	,,	,,	27002·1
		02·0	1n	,,	,,	
* 01·457		01·4	2	,,	,,	08·8
01·134	01·13	01·2	2	,,	,,	11·1
00·487		00·5	1	,,	,,	15·8
3698·016		3698·0	2	1·02	,,	33·9
* 97·921	3697·92		3	,,	,,	34·6
* 96·738	96·74	96·7	4	,,	,,	43·3
		96·0	1	,,	,,	
	94·30	94·1	1	,,	,,	61·1
* 93·740	93·74	93·7	2	,,	,,	65·2
	92·90			,,	,,	
	92·60	92·5 Rh	1	,,	,,	
	91·10	91·1	1	,,	,,	84·5
90·179	90·18	90·19 Pd	1	,,	,,	91·3
		87·5	1	,,	,,	
86·742	86·74	86·6	1	,,	,,	27116·6
* 86·109	86·11	86·1	4	,,	,,	20·6
85·204	85·20		2	,,	,,	27·9

* Rowland and Tatnall: 3732·170, 3731·048, 3730·737, 3730·577, 3728·173, 3727·073, 3726·239, 3725·117, 3719·468, 3717·822, 3717·146, 3716·314, 3715·705, 3712·444, 3705·496, 3703·343, 3702·369, 3701·456, 3697·906, 3696·725, 3693·734, 3686·086.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3683·730		3683·5	1	1·02	7·7	27138·7
		82·5	1n	,,	,,	
		81·8	1n	,,	,,	
* 78·465	3678·47	78·4	4	,,	,,	77·5
78·222	78·22	78·2	2	,,	,,	78·6
78·140			2	,,	,,	80·0
* 77·100	77·10	77·1	2	,,	,,	86·6
* 76·817	76·82	76·7	3	,,	,,	89·9
		76·4	1	,,	,,	
	75·60	75·7	1	,,	,,	98·7
* 75·408	75·41	75·4	3	,,	,,	27200·2
* 72·525		72·5	2	,,	,,	21·6
72·210		72·3	2	,,	,,	23·1
* 71·363		71·3	2	,,	,,	30·1
* 69·694	69·69	69·79	4	,,	,,	42·5
68·890		68·9	1	,,	,,	55·8
		67·1	1	,,	,,	
		65·4	1n	,,	,,	
		64·1	1	,,	,,	
* 63·526	63·53	63·53	5	,,	,,	88·4
* 61·727			2	,,	,,	27301·8
* 61·486	61·49	61·57	7	,,	,,	03·6
* 60·964	60·96	61·0	3	,,	,,	07·5
	60·25	60·2	2	,,	,,	12·8
	59·55			,,	,,	
		59·0	1	,,	,,	
57·716	57·72	57·82	1	1·01	,,	32·9
57·315	57·32	57·4	2	,,	,,	34·8
	56·50	56·7	1	,,	,,	40·9
56·112			2	,,	,,	43·8
* 54·559	54·56	54·55	4	,,	,,	55·6
53·857	53·86	53·9	2	,,	,,	60·6
	53·00	53·0	1	,,	,,	67·1
52·816			0	,,	,,	68·4
52·627			0	,,	,,	69·9
* 52·465	52·47	52·5	3	,,	,,	71·1
* 50·473	50·47	50·48	4	,,	,,	87·0
		50·0	1	,,	,,	
	49·75			,,	,,	
	48·85			,,	,,	
		48·0 Fe	1	,,	,,	
		47·5	1	,,	,,	
* 46·266	46·27	46·3	3	,,	,,	27417·6
45·827			1	,,	,,	20·9
		41·3	1	,,	,,	
* 40·791	40·79	40·7	4	,,	,,	51·3
* 38·163	38·16	38·2	2	,,	7·8	78·6
* 37·614	37·61	37·62	4	,,	,,	82·7
		37·0	1	,,	,,	
* 35·661	35·66	35·6	4	,,	,,	97·5
* 35·093	35·09	35·10	7	,,	,,	27501·8
* 34·063	34·06	34·1	4	,,	,,	09·6

* Rowland and Tatnall: 3678·456, 3677·098, 3676·808, 3675·400, 3672·521, 3671·355, 3669·688, 3663·520, 3661·721, 3661·525, 3660·961, 3654·549, 3652·460, 3650·465, 3646·262, 3640·786, 3638·161, 3637·612, 3635·658, 3635·084, 3634·064.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3632·545	3632·55	3632·6	1	1·01	7·8	27521·1
* 31·860	31·86	31·9	3	,,	,,	26·3
	31·65 Fe	31·7 Fe		,,	,,	
29·352			1	,,	,,	44·8
		28·8 Ir		,,	,,	
	28·50			,,	,,	
		28·1		,,	,,	
* 27·425	27·43	27·5	2	,,	,,	60·0
* 26·897	26·90	26·88	5	,,	,,	71·0
* 25·345	25·35	25·30	5	,,	,,	75·8
23·995			0	,,	,,	86·1
23·804	23·80	23·8	4	,,	,,	87·5
* 20·426	20·43	20·4	4	,,	,,	27613·2
* 19·334	19·33	19·4	4	,,	,,	21·6
	18·90 Fe	18·8 Fe		,,	,,	
* 17·090	17·09	17·2	4	1·00	,,	38·7
		15·4		,,	,,	
	15·05			,,	,,	
14·486		14·5	1	,,	,,	58·6
		13·3		,,	,,	
		12·6		,,	,,	
	12·30			,,	,,	
		11·6		,,	,,	
		10·8	1	,,	,,	
		09·6 Pd	1	,,	,,	
*3609·241			2	,,	,,	98·8
* 08·862	08·86	08·9	2	,,	,,	27701·8
		06·6	1	,,	,,	
06·297		06·3	1	,,	,,	21·4
* 05·792	05·79	05·8 Ir	3	,,	,,	25·4
		03·3	1	,,	,,	
		02·6	1	,,	,,	
* 01·627	01·63	01·7	2	,,	,,	57·4
		00·8	1	,,	,,	
*3599·913	3599·91	3599·95	4	,,	,,	70·7
99·548			0	,,	,,	73·4
		99·0	1	,,	,,	
		97·5	1	,,	,,	
* 96·315	96·32	96·28	5r	,,	,,	98·4
		95·8	1	,,	,,	
* 93·177	93·18	93·17	4r	,,	7·9	27822·6
	91·58	91·7	1	,,	,,	35·0
91·044	91·04	91·0	1	,,	,,	39·1
		90·7	1	,,	,,	
* 89·370	89·37	89·37	4	,,	,,	52·1
87·344	87·34	87·34	2	,,	,,	67·9
		85·5	1	,,	,,	
		85·3	1	,,	,,	
	85·17	85·0	1	,,	,,	84·8
*	84·21	84·3	2	,,	,,	92·3
	81·31 Fe	81·4 Fe	1	,,	,,	

* Rowland and Tatnall: 3631·859, 3627·433, 3626·886, 3625·339, 3620·434, 3619·348, 3617·100, 3609·247, 3608·878, 3605·785, 3601·630, 3599·914, 3596·342, 3593·178, 3589·360, 3584·349.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*3579·923	3579·92	3579·8	0	1·00	7·9	27925·7
	78·90	78·7	1	,,	,,	33·7
	77·55	77·6	1	0·99	,,	44·2
	77·10	77·1	2	,,	,,	47·7
	76·17			,,	,,	
		75·1	1	,,	,,	
* 74·744	74·74	74·7	3	,,	,,	66·1
	74·00			,,	,,	
		73·8 Ir	1	,,	,,	
		73·3	1	,,	,,	
	72·13	72·1	1	,,	,,	86·6
*		71·9	1	,,	,,	
* 70·743	70·74	70·74	1	,,	,,	97·6
		68·6	1	,,	,,	
* 67·308	67·31	67·3	2	,,	,,	28024·4
	66·59	66·6	2	,,	,,	30·0
		65·5 Fe	1	,,	,,	
* 64·945	64·95	65·0	0	,,	,,	43·0
* 64·714	64·71	64·7	1	,,	,,	44·8
* 64·517	64·52	64·6	0	,,	,,	46·4
		63·7	1	,,	,,	
		63·3	1	,,	,,	
	62·75	62·7	1	,,	,,	60·3
* 62·035	62·04	62·1	0	,,	,,	65·9
	61·83	61·7	1	,,	,,	67·6
		61·2	1	,,	,,	
	60·85	60·8 Os	2	,,	,,	75·4
	60·00	60·0	1	,,	,,	82·0
		59·8	1	,,	,,	
* 57·203	57·20	57·2	0	,,	,,	28104·1
		57·0	1	,,	,,	
* 56·779	56·78	56·8	0	,,	,,	07·4
* 54·002	54·00	53·9	1	,,	,,	29·4
	50·73	50·7	1	,,	8·0	55·2
* 50·420	50·42	50·4	2	,,	,,	58·4
	49·90	49·8	1	,,	,,	61·8
	48·70	48·6	1	,,	,,	71·3
* 47·136	47·14	47·1	1	,,	,,	83·7
		45·9	2b	,,	,,	
		42·7	1	,,	,,	
* 41·788	41·79	41·7	3	,,	,,	28226·3
		41·1	1	,,	,,	
		40·9	1	,,	,,	
		40·3	1	,,	,,	
* 39·518			2	,,	,,	44·8
* 39·418	39·42	39·40	2	,,	,,	45·2
* 38·100	38·10	38·03	3	,,	,,	55·8
	36·78	36·7	2	0·98	,,	66·3
* 35·985	35·99	36·0	2	,,	,,	72·7
* 35·529	35·53	35·5	2	,,	,,	76·3
* 32·965	32·97	32·95	2	,,	,,	96·8
* 31·545	31·55	31·5	3	,,	,,	28308·2
	29·26	29·4	2	,,	,,	26·5

* Rowland and Tatnall: 3579·924, 3574·748, 3571·913, 3570·748, 3567·309, 3564·949, 3564·719, 3564·509, 3562·043, 3557·207, 3556·773, 3553·998, 3550·419, 3547·131, 3541·777, 3539·521, 3539·415, 3538·100, 3535·988, 3535·537, 3532·962, 3531·543.

RUTHENIUM—*continued*.

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*3528·841	3528·84	3528·7	2	0·98	8·0	28328·9
	28·05			,,	,,	
	27·39	27·3	1	,,	,,	41·6
		26·6	1	,,	,,	
		26·4	1	,,	,,	
		25·7	1n	,,	,,	
	24·62	24·6	2	,,	,,	63·8
	24·16	24·0	2	,,	,,	67·5
		22·4	1	,,	,,	
		22·2	1	,,	,,	
* 20·285	20·29	20·22	4	,,	,,	98·9
* 19·795	19·80	19·80	3	,,	,,	28402·7
	19·10	19·1	1	,,	,,	08·4
	18·00			,,	,,	
16·046	16·05	16·0	0	,,	,,	33·0
		15·2	1n	,,	,,	
14·911			1	,,	,,	42·2
* 14·649	14·65	14·60	4	,,	,,	44·3
* 13·807	13·81		2	,,	,,	51·2
		13·0	1	,,	,,	
		11·5	1	,,	,,	
		10·5	1n	,,	,,	
09·870			2	,,	8·1	83·0
	09·35	09·30	4	,,	,,	87·2
		07·3	1n	,,	,,	
		06·9	1n	,,	,,	
		05·9	1n	,,	,,	
	04·65			,,	,,	
	03·60			,,	,,	
02·578	02·58	02·5	2	,,	,,	28542·3
01·510			1	,,	,,	53·1
*3499·098	3499·10	3499·05	10r	,,	,,	70·7
* 98·103	98·10	98·0	1	0·97	,,	79·6
* 96·293			2	,,	,,	93·6
* 96·145	96·15	96·1	2	,,	,,	94·8
* 94·410		94·2	3	,,	,,	28609·0
93·377	93·38	93·2	2	,,	,,	17·5
92·256	92·26	92·0	1	,,	,,	26·7
90·879	90·88	90·8	1	,,	,,	46·8
	90·30	90·3	1	,,	,,	42·7
89·895			1	,,	,,	53·7
		88·2	1n	,,	,,	
	87·87	87·7	1	,,	,,	62·7
86·948			2	,,	,,	70·3
86·360			2	,,	,,	74·0
		85·6	1n	,,	,,	
	83·65	83·7	1	,,	,,	97·4
* 83·463	83·46		2	,,	,,	98·9
* 83·317	83·32	83·3	2	,,	,,	28700·1
82·499		82·5	2	,,	,,	06·8
		82·0	1	,,	,,	
	81·66			,,	,,	
* 81·465	81·47	81·42	4	,,	,,	15·4

* Rowland and Tatnall: 3528·832, 3520·286, 3519·785, 3514·631, 3513·799, 3499·095, 3498·086, 3496·272, 3496·131, 3494·404, 3483·438, 3483·317, 3481·449.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3481·044			0	0·97	8·1	28718·8
80·295	3480·30	3480·2	2	,,	,,	25·0
	79·45	79·5	2	,,	,,	32·0
		77·6	1n	,,	,,	
77·350		77·2	0	,,	,,	55·0
	75·00	75·0	1	,,	,,	68·9
* 73·900	73·90	73·90	5	,,	,,	78·0
	73·45	73·4	1	,,	,,	81·7
72·843	72·84	72·7	2	,,	,,	86·8
	72·39	72·4	2	,,	,,	90·5
	70·20 } 69·80 }	70·0	1	,,	,,	
		69·5	1	,,	,,	
		68·1	1n	,,	,,	
* 67·190	67·19	67·3	2	,,	8·2	28833·6
65·437	65·44	65·5	1	,,	,,	48·1
63·751			0	,,	,,	62·2
* 63·289	63·29	63·2	4	,,	,,	64·0
* 62·208	62·21	62·1	2	,,	,,	66·1
	61·55			,,	,,	
59·736		59·6	2	,,	,,	95·7
		58·3	1b	0·96	,,	
57·849			0	,,	,,	28911·5
		57·3	1	,,	,,	
	57·05			,,	,,	
* 56·769	56·77	56·7	4	,,	,,	20·5
55·888			2	,,	,,	27·9
55·548		55·6	2	,,	,,	30·8
53·373			0	,,	,,	49·0
53·056	53·06	53·0	4	,,	,,	51·7
		52·1	1	,,	,,	
51·014			0	,,	,,	68·8
49·608			0	,,	,,	80·6
* 49·105	49·11	49·1	4	,,	,,	84·9
	46·96	46·8	1n	,,	,,	
46·630			2	,,	,,	29005·6
46·227		46·3	2	,,	,,	09·0
46·095	46·10		0	,,	,,	10·1
45·675			0	,,	,,	13·7
45·453			1	,,	,,	16·4
		45·3	1	,,	,,	
44·574			1	,,	,,	23·0
43·818			0	,,	,,	29·3
43·309			0	,,	,,	33·6
41·942			0	,,	,,	45·3
* 40·361	40·36	40·4	4	,,	,,	58·5
39·835			2	,,	,,	63·0
38·819			0	,,	,,	71·5
* 38·522	38·52	38·5	4	,,	,,	74·1
* 36·886	36·89		5r	,,	,,	87·9
* 36·481			2	,,	,,	91·3
36·237			0	,,	,,	93·4
* 35·340	35·34	35·3	4	,,	,,	29101·0
	34·93			,,	,,	

* Rowland and Tatnall: 3473·892, 3467·192, 3463·286, 3462·186, 3456·763, 3449·107, 3440·351, 3438·510, 3436·883, 3436·475, 3435·327.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3434·325	3434·33		0	0·96	8·2	29109·6
* 33·406	33·41	3433·45	4	,,	,,	17·4
* 32·909	32·91	32·9	4	,,	,,	21·5
32·560		32·5	0	,,	,,	24·6
* 32·354	32·35		3	,,	,,	26·2
31·905			0	,,	,,	37·3
* 30·910	30·91	31·05	4	,,	,,	38·5
30·568		30·6	0	,,	,,	41·4
* 29·702	29·70	29·6	4	,,	,,	48·8
* 28·790	28·79	28·60	2	,,	,,	56·5
* 28·476			4r	,,	,,	59·2
27·717	27·72		0	,,	,,	65·6
* 26·120	26·09	26·2	2	,,	,,	79·2
	24·39	24·5	1	,,	,,	
		24·3	1	,,	,,	94·1
22·578			2	,,	,,	29209·4
20·881			0	,,	,,	23·9
* 20·243	20·24	20·2	4	,,	,,	29·3
		20·0	1n	,,	,,	
* 19·394	19·39		2	,,	,,	36·6
* 18·125	18·13	18·1	2	,,	,,	47·5
17·790			1	0·95	,,	50·4
* 17·493	17·49	17·45	7	,,	,,	52·9
	16·90	16·7	1	,,	,,	58·0
* 16·329	16·33	16·4	1	,,	,,	62·9
		15·6	1	,,	,,	
* 14·787	14·79	14·7	3	,,	,,	76·1
		14·5	1	,,	,,	
14·422			2	,,	8·3	79·2
14·130			0	,,	,,	80·7
13·870			0	,,	,,	75·4
* 12·947	12·95	12·8	3	,,	,,	91·9
12·221			2	,,	,,	98·1
* 11·768	11·77	11·6	4	,,	,,	29302·0
	10·84	10·7	2	,,	,,	10·0
	10·10			,,	,,	
09·707			2	,,	,,	19·7
* 09·420	09·42	09·42	5	,,	,,	22·2
		09·2	2	,,	,,	
07·042			0	,,	,,	42·7
* 06·736			2	,,	,,	45·3
* 06·017			2	,,	,,	51·5
05·426			0	,,	,,	56·6
03·924		03·7	1	,,	,,	75·4
		02·7	1	,,	,,	
		02·00	4	,,	,,	
* 01·878	01·88		3	,,	,,	87·2
* 01·637	01·64		2	,,	,,	89·3
01·304		01·4	0	,,	,,	92·1
00·890			2	,,	,,	95·8
00·738			1	,,	,,	97·1

* Rowland and Tatnall: 3433·397, 3432·896. 3432·348, 3430·908, 3429·689, 3428·769, 3428·460, 3426·089, 3420·236, 3419·389, 3418·117, 3417·466, 3416·320, 3414·782, 3412·939, 3411·780, 3409·424, 3406·731, 3406·025, 3401·876, 3401·646.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3400·116			0	0·95	8·3	29402·5
		3399·4	1	,,	,,	
	3399·15			,,	,,	
3399·040	99·04		0	,,	,,	11·8
		98·9	2	,,	,,	
98·470			0	,,	,,	16·7
96·967			4	,,	8·4	32·2
96·060			0	,,	,,	37·5
95·465		95·3	0	,,	,,	42·6
		94·0	1n	,,	,,	
* 92·654	92·65	92·68	4	,,	,,	67·0
* 92·032	92·03	92·0	2	,,	,,	72·4
91·042			2	,,	,,	81·0
* 89·639	89·64	89·6	4	,,	,,	93·3
89·250	89·25	89·3	0	,,	,,	96·6
* 88·849	88·85	88·8	4	,,	,,	29500·1
87·967	87·97	88·0	0	,,	,,	07·8
* 87·368		87·3	2	,,	,,	13·0
86·390		86·3	2	,,	,,	21·5
* 85·838			2	,,	,,	26·4
* 85·609	85·61	85·7	2	,,	,,	28·4
* 85·303	85·30	85·2	4	,,	,,	31·0
83·053			0	,,	,,	40·6
		82·3	1	,,	,,	
		81·6	1	,,	,,	
81·040		81·0	2	,,	,,	68·3
* 80·301	80·30	80·3	4	,,	,,	74·7
* 79·747	79·75	79·6	4	,,	,,	79·6
79·402		79·4	2	,,	,,	82·6
* 78·165	78·17	78·2	4	,,	,,	93·4
76·186			1	0·94	,,	29610·8
75·377			2	,,	,,	17·9
75·036			2	,,	,,	20·9
* 74·790	74·79	74·7	4	,,	,,	23·1
74·115	74·12		2	,,	,,	29·0
	73·45	73·5	1	,,	,,	34·8
		73·3 Pd	1	,,	,,	
72·922	72·92		0	,,	,,	39·5
* 71·990	71·99		4	,,	,,	47·7
71·793		71·8	0	,,	,,	49·4
70·720	70·72		2	,,	,,	58·9
	70·19	70·10	4	,,	,,	63·5
69·813		69·7	2	,,	,,	66·4
69·433	69·43	69·40	2	,,	,,	70·2
* 68·588	68·59	68·58	6	,,	,,	77·6
68·053			0	,,	,,	82·3
67·868			0	,,	,,	84·0
65·470			0	,,	,,	29705·1
65·163			0	,,	,,	07·8
64·933		64·8	1	,,	,,	09·9
* 64·230	64·23	64·1	4	,,	,,	
* 62·457	62·46	62·3	2	,,	,,	16·0

* Rowland and Tatnall: 3392·672, 3392·032, 3389·644, 3388·846, 3387·369, 3385·836, 3385·608, 3385·207, 3380·308, 3379·744, 3378·170, 3374·790, 3371·992, 3368·604, 3368·524, 3364·243, 3362·473.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	1/λ −	
*3362·142		3362·1	4	0·94	8·4	29731·7
61·295	3361·30	61·2	2	,,	,,	34·5
	60·20	60·0	1	,,	,,	42·0
* 59·230	59·23	59·30	6	,,	8·5	59·2
58·110			0	,,	,,	70·2
56·598			2	,,	,,	83·8
56·327		56·3	2	,,	,,	86·1
55·803		55·7	2	,,	,,	90·7
54·001			2	,,	,,	29806·6
* 53·776		53·6	4	,,	,,	08·3
53·444	53·44	53·3	2	,,	,,	11·6
53·122			1	,,	,,	14·5
* 52·060		52·0	4	,,	,,	23·9
50·681			2	,,	,,	36·3
50·363	50·36	50·30	0	,,	,,	39·1
50·236			2	,,	,,	40·2
49·822	49·82		0	,,	,,	43·8
* 48·833			2	,,	,,	52·6
* 48·145	48·15	48·0	2	,,	,,	58·8
* 47·748	47·75	47·6	4	,,	,,	62·4
46·360			0	,,	,,	73·9
* 45·450	45·45	45·3	4	,,	,,	83·7
44·934			2	,,	,,	87·5
* 44·666	44·67		4	,,	,,	89·8
	43·32	43·2	2	,,	,,	92·9
42·999			0	,,	,,	29904·8
42·854	42·85	42·7	0	,,	,,	06·4
* 41·809	41·81	41·7	4	,,	,,	15·4
* 41·361		41·3	1	,,	,,	19·3
* 41·230			2	,,	,,	20·4
39·932	39·93	39·8	2	,,	,,	37·6
* 39·691	39·69	39·72	6	,,	,,	34·4
39·092			0	,,	,,	39·7
38·849			2	0·93	,,	41·9
		38·3	1n	,,	,,	
37·963	37·96	37·8	4	,,	,,	49·9
36·774		36·6	3	,,	,,	60·6
36·296			2	,,	,,	64·8
* 35·822	35·82	35·7	4	,,	,,	69·1
34·764			0	,,	,,	78·6
* 32·768		32·7	2	,,	,,	96·6
32·483			0	,,	,,	99·2
* 32·186		32·1	4	,,	,,	30001·8
		31·2	1	,,	,,	
28·583			2	,,	,,	34·3
* 27·831		27·6	4	,,	,,	41·1
25·373	25·37	25·4	2	,,	,,	53·3
* 25·136	25·14	25·0	4	,,	8·6	65 3
24·509	24·51	24·6	0	,,	,,	71·3
24·077			2	,,	,,	74·9
23·226			4	,,	,,	82·6
22·368		22·2	4	,,	,,	90·4

* Rowland and Tatnall: 3362·151, 3359·239, 3353·790, 3352·075, 3348·847, 3348·153, 3347·757, 3345·457, 3344·679, 3341·811, 3341·365, 3341·230, 3339·690, 3335·836, 3332·781, 3332·190, 3327·843, 3325·136.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3321·634			0	0·93	8·6	30097·1
21·385		3321·2	2	,,	,,	99·3
19·944			1	,,	,,	30112·4
19·655			1	,,	,,	15·0
* 18·992	3318·99	18·8	6	,,	,,	21·0
* 18·012	18·01	17·9	4	,,	,,	29·9
	17·66	17·5d	2	,,	,,	33·1
17·045	17·05	17·0	1	,,	,,	38·7
* 16·523	16·52	16·55	6	,,	,,	43·4
* 15·590			2	,,	,,	51·9
* 15·365	15·37	15·30	3	,,	,,	54·0
15·181			2	,,	,,	55·6
14·203			2	,,	,,	64·5
	12·99	12·7	1	,,	,,	75·6
12·348			1	,,	,,	81·4
12·068			0	,,	,,	84·0
11·388			0	,,	,,	90·2
* 11·090	11·09	11·0	4	,,	,,	92·9
10·220		10·2	0	,,	,,	30200·9
09·965	09·97		0	,,	,,	06·1
	09·38	09·2	1	,,	,,	08·5
	09·00			,,	,,	
08·751		08·8	0	,,	,,	14·3
08·122	08·12	08·1	4	,,	,,	20·0
07·679		07·7	2	,,	,,	24·1
	06·81	06·6	1	,,	,,	32·1
* 06·305	06·31	06·2	4	,,	,,	36·5
05·804			0	,,	,,	41·1
	05·15	05·1	2	,,	,,	47·2
* 04·948		04·9	2	,,	,,	49·1
04·772			0	,,	,,	50·7
04·634			2	,,	,,	51·9
04·418			0	,,	,,	53·9
* 04·141	04·14	04·0	4	,,	,,	56·5
02·312			1	,,	,,	73·2
	01·94	01·9 Pt	1	,,	,,	76·6
01·726	01·73	01·6	5	,,	,,	78·6
	01·35	01·1	2	,,	,,	81·9
3299·926		00·0	0	,,	,,	95·1
* 99·479	3299·48	3299·3	2	0·92	,,	99·2
* 98·559	98·56	98·4	4	,,	,,	30307·7
* 98·096	98·10	98·0	3	,,	,,	11·9
* 97·393	97·39	97·2	3	,,	,,	19·4
* 96·786	96·79	96·6	2	,,	,,	24·0
* 96·252	96·25	96·1	4	,,	,,	28·9
94·926			0	,,	,,	41·1
* 94·269	94·27	94·38	6	,,	,,	47·1
92·390		92·1	2	,,	,,	64·4
91·789		91·8	2	,,	,,	70·2
		91·5	1n	,,	,,	
91·250			2	,,	,,	75·0
		91·0	1	,,	,,	

* Rowland and Tatnall: 3318·965, 3318·025, 3316·524, 3315·579, 3315·363, 3311·096, 3306·310, 3304·951, 3304·126, 3299·466, 3298·549, 3298·089, 3297·389, 3296·780, 3296·248, 3294·233.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3289·389		3289·3	2n	0·92	8·6	30392·2
	3286·55	86·8	1	,,	8·7	30418·3
86·040			1	,,	,,	23·0
85·505		85·7	2	,,	,,	28·0
* 85·067			4	,,	,,	32·1
	84·46	84·5	1	,,	,,	37·7
		84·3	2	,,	,,	
82·744		82·5	0	,,	,,	53·6
81·995			2	,,	,,	60·6
81·735	81·74	81·5	0	,,	,,	63·0
	81·26	81·2	1	,,	,,	67·3
80·678			1	,,	,,	72·9
80·599		80·5	2	,,	,,	73·5
79·521			2	,,	,,	83·5
* 77·699	77·70	77·6	4	,,	,,	30500·5
76·820		76·6	0	,,	,,	08·7
	75·87	75·7	1	,,	,,	17·5
* 74·831	74·83	74·7	5	,,	,,	27·2
73·765	73 77	73·6	0	,,	,,	37·1
* 73·217	73·22	73·1	5	,,	,,	42·3
72·366			0	,,	,,	50·2
		72·0	1n	,,	,,	
71·746			0	,,	,,	56·0
		71·2	1n	,,	,,	
70·388		70·2	2	,,	,,	68·7
	69·80			,,	,,	
69·336			2	,,	,,	78·5
69·087	69·05	68·93	2	,,	,,	80·9
* 68·345	68·35	68·3	5	,,	,,	87·8
67·269		67·2 Os	0	,,	,,	97·9
	67·07			,,	,,	
66·588	66·59	66·4	4	,,	,,	30604·3
		66·1	1	,,	,,	
* 64·808	64·81	64·90	2	,,	,,	31·0
* 64·692						32·1
* 63·988		63·9	3	,,	,,	39·7
63·740		63·7	3	,,	,,	41·0
		62·5 Os	0	,,	,,	
		61·7	1n	,,	,,	
* 61·257		61·1	1	,,	,,	54·3
* 60·494	60·49	60·45	3	,,	,,	61·5
* 60·304	60·30	60·1	5	,,	,,	63·3
* 59·811	59·81	59·6	2	,,	,,	67·9
59·111	59·11	59·0	4	0·91	,,	74·5
* 58·176	58·18	58·0	0	,,	,,	83·3
	57·94	57·7	3	,,	,,	90·6
		57·2	1	,,	,,	
56·746			0	,,	,,	96·8
* 56·477	56·48	56·3	4	,,	,,	99·3
55·356		55·2	1	,,	,,	30709·9
55·173			0	,,	,,	11·6
* 54·856	54·86	54·6	4	,,	,,	14·6

* Rowland and Tatnall: 3285·066, 3277·697, 3274·834, 3273·208, 3268·346 3264·790, 3264·688, 3263·984, 3261·256, 3260·477, 3260·301, 3259·805, 3258·173 3256·460, 3254·834.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*3254·674	3254·67	3254·5	4	0·91	8·7	30715·4
	53·36	53·2	2	,,	,,	28·8
53·136			2	,,	,,	30·9
* 53·038			1	,,	,,	31·8
52·683		52·8	2	,,	8·8	35·1
52·400			0	,,	,,	37·7
* 52·031	52·03		3	,,	,,	41·1
		50·7 Pd		,,	,,	
* 51·464		51·4	3	,,	,,	46·6
	51·10			,,	,,	
50·605			1	,,	,,	59·0
50·065	50·07	49·9	2	,,	,,	59·8
48·977			2	,,	,,	70·1
	48·04	48·0	1	,,	,,	79·0
47·501	47·50	47·4	0	,,	,,	84·1
46·380	46·38	46·2	0	,,	,,	94·7
45·746	45·75	45·6	0	,,	,,	30800·8
44·719			0	,,	,,	10·3
44·585			1	,,	,,	11·6
44·475		44·4	0	,,	,,	12·6
* 43·638	43·64	43·4	2	,,	,,	20·8
42·978		42·8 Pd	2	,,	,,	28·9
42·283	42·28	42·1	2	,,	,,	33·6
41·884		41·6 Ir	0	,,	,,	37·5
41·643	41·64		0	,,	,,	39·7
* 41·362	41·36	41·2	4	,,	,,	42·4
* 39·745	39·75	39·5	3	,,	,,	57·8
38·904			2	,,	,,	65·8
* 38·667	38·67	38·4	5	,,	,,	68·1
38·132			0	,,	,,	73·2
36·101	36·10		2	,,	,,	92·6
	35·85	35·7	2	,,	,,	95·0
35·431			0	,,	,,	99·0
35·230		35·0	2	,,	,,	30900·9
34·920		34·7	2	,,	,,	03·9
	34·39	34·3	2	,,	,,	09·0
33·650			0	,,	,,	16·0
* 32·881	32·89	32·7	4	,,	,,	23·4
32·180			1	,,	,,	30·1
31·869	31·87	31·5	0	,,	,,	33·0
30·738			2	,,	,,	43·9
29·881		28·7	2	,,	,,	52·1
28·850			0	,,	,,	62·0
* 28·651	28·65	28·63	4	,,	,,	63·9
* 28·276		28·1	2	,,	,,	67·5
* 28·021		27·8	3	,,	,,	69·9
* 27·016	27·02	26·8	2	,,	,,	79·5
* 26·497	26·50	26·4	5	,,	,,	85·6
25·418			0	,,	,,	94·9
	25·03	24·9	1	,,	,,	98·6
24·772		24·7	2	,,	8·9	31001·0
	24·18	24·0	1	,,	,,	07·7

* Rowland and Tatnall: 3254·670, 3253·041, 3252·029, 3251·459, 3243·632, 3241·360, 3239·727, 3238·660, 3232·872, 3228·651, 3228·280, 3228·007, 3227·027, 3226·502.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3223·723			0	0·91	8·9	31011·1
* 23·393	3223·39	3223·2	4	,,	,,	14·3
	22·07	21·9	2	,,	,,	27·1
21·493	21·49	21·3d	1	,,	,,	32·6
* 21·303			2	,,	,,	34·4
20·899	20·90		2	0·90	,,	47·1
* 20·195	20·20	20·1	2	,,	,,	45·1
	19·49	19·4	2	,,	,,	51·9
19·274			1	,,	,,	54·0
		18·9	1	,,	,,	
	17·96	17·7	2	,,	,,	66·7
* 16·641	16·64	16·5	4	,,	,,	79·4
		16·0	1	,,	,,	
15·613			0	,,	,,	89·4
14·475		14·3	2	,,	,,	31100·4
	13·33	13·3	1	,,	,,	11·4
* 13·098	13·10	13·0	3	,,	,,	13·7
	12·30			,,	,,	
		12·0 Ir	1n	,,	,,	
	11·38	11·3	1	,,	,,	30·4
	10·95			,,	,,	
		10·6 Pd	1	,,	,,	
10·287	10·29	10·1	2	,,	,,	41·0
09·758		09·6	1	,,	,,	46·1
	09·43			,,	,,	
08·865			1	,,	,,	54·8
08·542			3	,,	,,	57·9
08·405			0	,,	,,	59·2
07·751	07·75	07·7	0	,,	,,	65·6
	07·43	07·3	2	,,	,,	68·9
	06·82	06·7	2	,,	,,	74·6
05·428	05·43	05·3	2	,,	,,	88·2
	05·08	05·0		,,	,,	91·5
	04·36	04·2	2	,,	,,	98·6
	03·62	03·6	2	,,	,,	31205·8
		03·0	1	,,	,,	
02·705		02·5	2	,,	,,	14·7
* 01·604			3	,,	,,	25·4
01·372	01·37	01·38	2	,,	,,	27·7
3199·238		3199·0 Ir	0	,,	,,	48·5
	3198·74	98·6	2	,,	,,	53·4
98·437		98·5	2	,,	,,	56·4
97·603		97·7	0	,,	,,	64·5
* 96·718	96·72	96·5	4	,,	,,	73·2
	95·85	95·6	1	,,	,,	81·7
95·438			1	,,	,,	85·7
95·137	95·14	95·1	0	,,	,,	88·6
93·617		93·5	2	,,	,,	31303·5
	92·52	92·5d	1	,,	,,	04·5
* 92·171	92·17	92·1	2	,,	,,	07·9
91·900		91·7	2	,,	,,	20·4
91·303			1	,,	,,	26·2
* 90·088	90·09	89·9	4	,,	,,	38·2

* Rowland and Tatnall: 3223·394, 3221·311, 3220·199, 3216·646, 3213·105, 3201·631, 3196·725, 3192·191, 3190·096.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*3189·835		3189·7	3	0·90	8·9	31340·7
89·418		89·2	2	,,	,,	44·7
		88·8	1	,,	,,	
88·713		88·5	2	,,	,,	51·7
* 88·463	3188·46	88·45	5	,,	,,	54·1
88·057			2	,,	,,	58·2
86·867			1	,,	,,	69·9
* 86·171	86·16	86·0	4	,,	,,	76·7
85·553			2	,,	,,	82·8
85·276	85·28	85·3	0	,,	,,	85·5
		84·9	1	,,	,,	
		84·1	1	,,	,,	
		83·9	1	,,	,,	
	83·54	83·4	2	,,	,,	31402·7
		82·0	1	,,	,,	
81·312		81·4	0	0·89	,,	24·7
81·126			0	,,	,,	26·5
80·569			0	,,	9·0	31·9
79·380	79·38	79·2	2	,,	,,	43·6
78·843			1	,,	,,	49·0
* 77·159	77·16	77·18	4	,,	,,	65·6
76·401		76·2	3	,,	,,	73·2
	75·32	75·30	4	,,	,,	84·0
		75·10	4	,,	,,	
* 74·243	74·24	74·1 Os ?	4	,,	,,	94·5
73·500			2	,,	,,	31501·9
73·221			2	,,	,,	04·7
72·778	72·78	72·6	0	,,	,,	09·1
71·352			2	,,	,,	23·3
70·196		70·0	2	,,	,,	34·8
* 68·648	68·65	68·5	5	,,	,,	50·2
68·355			1	,,	,,	53·1
67·514	67·51	67·58	0	,,	,,	61·5
	66·68	66·4	2	,,	,,	69·8
	66·24	66·0	2	,,	,,	74·1
65·507			0	,,	,,	81·5
65·307	65·31		1	,,	,,	83·5
65·086		65·0	0	,,	,,	85·7
64·939	64·94	65·0	0	,,	,,	87·2
		64·7	1	,,	,,	
		64·1	1	,,	,,	
		64·0	1	,,	,,	
63·186	63·30	63·25	0	,,	,,	31604·7
	60·80	60·78	4	,,	,,	28·6
* 60·036	60·04	60·05	4	,,	,,	36·2
59·003 Ca ?	59·00	58·7	4	,,	,,	46·5
57·739		57·5	2	,,	,,	59·2
		57·3	1	,,	,,	
		57·1	1	,,	,,	
56·917			2	,,	,,	67·5
56·733			0	,,	,,	69·3
	55·90			,,	,,	
		55·4	1	,,	,,	

* Rowland and Tatnall: 3189·843, 3188·468, 3186·162, 3177·170, 3174·254, 3168·678, 3160·042.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
3154·543			2	0·89	9·0	31691·3
* 53·927	3153·93	3153·7	4	,,	,,	97·5
	52·35	52·2	1	,,	,,	31713·3
51·780			1	,,	,,	19·1
	51·25	51·3	1	,,	,,	24·4
* 50·803	50·80	50·5	4	,,	,,	28·9
50·283			1	,,	,,	34·2
		49·7	1	,,	,,	
		49·3	1	,,	,,	
48·593	48·59	48·7	2	,,	,,	51·2
48·138			0	,,	,,	55·8
47·547	47·55	47·62	0	,,	,,	61·8
* 47·323			2	,,	,,	64·0
46·183	46·18	46·0	2	,,	9·1	75·5
44·820			2	,,	,,	89·0
* 44·369	44·37	44·2	4	,,	,,	93·8
43·764	43·76	43·80	0	,,	,,	31800·0
	43·46	43·40	4	,,	,,	03·0
	41·66	41·5	2	0·88	,,	21·2
* 41·081	41·08	40·9	4	,,	,,	27·1
* 40·596		40·4	3	,,	,,	29·0
40·201			1	,,	,,	36·0
39·379	39·65	39·5 Pt ?	2	,,	,,	41·6
38·884			2	,,	,,	49·4
		38·0	1	,,	,,	
37·036			0	,,	,,	68·2
* 36·663	36·66		3	,,	,,	71·9
36·451		36·5	1	,,	,,	74·1
36·044	36·04	35·98	2	,,	,,	78·3
	35·48			,,	,,	
35·170		35·1	0	,,	,,	87·2
34·895	34·90	34·98	1	,,	,,	89·1
33·800			2	,,	,,	31901·0
		33·5 Ir	1	,,	,,	
* 32·988		32·99	4	,,	,,	09·3
		32·6	2	,,	,,	
		32·5	2	,,	,,	
32·122			1	,,	,,	18·2
30·709			0	,,	,,	32·5
* 29·935			3	,,	,,	40·4
29·717		29·7	2	,,	,,	42·7
29·574		29·5	0	,,	,,	44·1
		28·8	1n	,,	,,	
28·539			2	,,	,,	54·7
	28·07	28·05	4	,,	,,	59·5
27·643			0	,,	,,	63·9
27·387			1	,,	,,	66·5
26·730	26·73	26·75	2	,,	,,	73·2
* 26·068			4	,,	,,	80·0
		25·7	1	,,	,,	
	24·98			,,	,,	
* 24·709		24·6	2	,,	,,	93·9

* Rowland and Tatnall: 3153·941, 3150·816, 3147·326, 3144·383, 3141·094, 3140·604, 3136·671, 3132·995, 3129·951, 3126·075, 3124·720.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
*3124·481	3124·48		2	0·88	9·1	31996·2
* 24·277	24·28	3124·1	4	,,	,,	98·3
		23·8	2	,,	,,	
23·610			0	,,	,,	32005·1
22·970			0	,,	,,	11·7
22·108			1	,,	,,	20·5
	20·90			,,	,,	
20·650		20·7	1	,,	,,	35·5
* 18·792		18·6	4	,,	,,	54·6
* 18·170		18·0	4	,,	,,	61·0
17·563			0	,,	,,	67·2
17·181			0	,,	,,	71·1
16·945			1	,,	,,	83·6
		16·5	1n	,,	,,	
15·536		15·5	0	,,	,,	88·1
	14·53	14·4	1n	,,	9·2	98·5
13·756	13·76	13·8 Pd	0	,,	,,	32106·4
13·502		13·3	2	,,	,,	09·0
* 12·782	12·78	12·5	2	,,	,,	16·4
12·408		12·3	2	,,	,,	20·3
* 12·012	12·01		3	,,	,,	24·3
		11·8	1	,,	,,	
	11·24	11·1	1	,,	,,	32·3
* 10·641	10·64	10·5	4	,,	,,	38·8
10·147			0	,,	,,	43·6
		09·5	1n	,,	,,	
08·526		08·3	2	,,	,,	61·4
* 07·829			3	,,	,,	67·6
07·698	07·70	07·72	0	,,	,,	68·9
07·373			0	,,	,,	72·3
* 06·942	06·94	06·7	3	,,	,,	76·8
05·910			0	,,	,,	87·5
* 05·524			2	,,	,,	91·5
05·382	05·38	05·2	2	,,	,,	92·9
04·570			2	,,	,,	32201·4
04·070			0	,,	,,	06·5
	03·51	03·3	2	,,	,,	12·3
	02·50	02·5	1	,,	,,	25·4
		02·2	1	,,	,,	
		01·7	1	0·87	,,	
	01·59	01·4	1	,,	,,	32·3
* 00·953	3000·95	3000·95	4	,,	,,	38·9
		99·8	1	,,	,,	
*3099·390	99·39	99·40	5	,,	,,	55·2
98·954			0	,,	,,	58·0
	98·05	97·9	2	,,	,,	63·0
* 97·706	97·71	97·6	4	,,	,,	72·7
*		97·2	1	,,	,,	
* 96·672	96·67	96·65	6	,,	,,	83·6
96·062		96·0	0	,,	,,	89·9
95·640			0	,,	,,	94·3
* 94·500	94·64	94·5	2	,,	,,	32306·2
	93·01			,,	,,	

* Rowland and Tatnall: 3124·480, 3124·279, 3118·799, 3118·182, 3112·792, 3112·031, 3110·650, 3107·825, 3106·954, 3105·523, 3100·945, 3099·390, 3097·708, 3097·337, 3096·669, 3094·507.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
3092·351			0	0·87	9·2	32328·6
92·085			0	,,	,,	31·4
* 91·974		3091·8	2	,,	,,	35·0
91·004			2	,,	,,	42·7
	3090·54	90·5	1	,,	,,	47·6
* 90·341	90·34		2	,,	,,	49·7
* 89·915	89·92	89·7	4	,,	,,	54·1
* 89·252	89·25	89·2	4	,,	,,	61·1
88·362			0	,,	,,	70·4
88·177	88·18	88·1	2	,,	,,	72·3
88·050			0	,,	,,	73·7
87·039			2	,,	,,	84·2
86·888			1	,,	,,	85·9
86·631	86·63		2	,,	,,	88·6
* 86·181	86·18	86·0	4	,,	,,	93·3
85·597			0	,,	,,	99·4
84·728			0	,,	,,	32408·6
* 84·631		84·5	2	,,	,,	09·6
* 83·252		83·0	3	,,	9·3	24·0
81·946	81·95	81·7	0	,,	,,	37·7
81·489	81·49	81·3	0	,,	,,	42·5
81·218			1	,,	,,	45·4
* 81·009	81·01		4	,,	,,	47·7
80·292		80·3	4	,,	,,	55·2
79·953		80·1	0	,,	,,	63·3
	79·27	79·1	1	,,	,,	65·9
78·209			1	,,	,,	77·1
77·657			2	,,	,,	82·9
77·175	77·18	77·0	2	,,	,,	88·0
* 76·886		76·8	2	,,	,,	91·1
75·412	75·41	75·3	1	,,	,,	32506·6
* 73·440	73·50		4	,,	,,	27·5
	72·42	72·3	2	,,	,,	38·3
71·824			0	,,	,,	44·6
* 71·721			0	,,	,,	45·7
71·586		71·5	2	,,	,,	47·1
		70·6	1	,,	,,	
		70·3	1	,,	,,	
69·289			2	,,	,,	71·5
* 68·355	68·36	68·2	4	,,	,,	81·4
		67·5	1	,,	,,	
		66·4	2	,,	,,	
* 64·958	64·96	64·95	4	,,	,,	32617·6
		63·3	1	,,	,,	
62·155	62·16	62·0	2	0·86	,,	47·3
	60·67	60·4	2	,,	,,	63·2
60·346	60·37	60·2	0	,,	,,	66·6
* 59·284	59·28	59·1	3	,,	,,	78·3
* 58·909			1	,,	,,	82·1
58·762	58·76	58·6	2	,,	,,	83·6
57·468	57·47	57·2	3	,,	,,	97·5
56·971	56·97	56·92	0	,,	,,	32702·8

* Rowland and Tatnall: 3091·980, 3090·348, 3089·916, 3089·259, 3086·182, 3084·637, 3083·257, 3081·010, 3076·883, 3073·442, 3071·711, 3068·363, 3064·951, 3359·275, 3058·891.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3056·877			0	0·86	9·3	32703·8
56·192			4	,,	,,	11·1
* 55·042	3055·04		4	,,	,,	23·5
		3054·8	2	,,	,,	
		54·6	1	,,	,,	
53·450			0	,,	,,	40·4
52·445			1	,,	9·4	51·2
51·974			0	,,	,,	56·3
51·704			2	,,	,,	59·2
50·504			0	,,	,,	72·1
50·309		50·3	1	,,	,,	74·1
	49·32	49·32		,,	,,	84·8
49·174			0	,,	,,	86·4
* 48·897	48·90	48·7	4	,,	,,	89·3
* 48·606	48·61	48·4	4	,,	,,	92·5
48·442			0	,,	,,	94·2
	47·88	47·6	2	,,	,,	32800·3
47·108		47·0	0	,,	,,	08·6
46·356	46·36	46·1	2	,,	,,	16·7
46·114			2	,,	,,	19·3
* 45·833	45·83	45·6	4	,,	,,	22·3
45·630			0	,,	,,	24·5
		44·5	1	,,	,,	
44·077			0	,,	,,	41·2
43·161			1	,,	,,	51·1
* 42·953	42·95	42·7 Ir	2	,,	,,	53·4
* 42·598	42·60	42·3	3	,,	,,	57·2
42·025			1	,,	,,	63·4
* 40·418	40·42	40·2	3	,,	,,	80·9
40·071	40·07	39·9	2	,,	,,	84·6
39·586			0	,,	,,	90·3
38·851		38·6	0	,,	,,	97·8
* 38·289		38·1	2	,,	,,	32903·9
38·078		37·9	2	,,	,,	06·0
37·845		37·0	2	,,	,,	08·7
36·580	36·58	36·53	1	,,	,,	22·3
	35·93	35·6	2	,,	,,	29·4
35·578		35·3	3	,,	,,	33·2
* 34·167	34·17	33·8	4	,,	,,	48·4
* 33·562	33·56	33·4	4	,,	,,	55·1
	33·16	33·0	1n	,,	,,	59·4
32·771	32·77	32·3	0	,,	,,	63·7
32·026		31·5	2	,,	,,	71·6
		31·1		,,	,,	
30·890		29·2	2	,,	,,	84·0
30·801		30·7 Os	2	,,	,,	84·2
	29·04	28·9		,,	,,	33004·2
28·785			0	,,	,,	07·1
27·910	27·91	27·7	0	,,	,,	16·7
27·678			0	,,	,,	19·2
27·361			0	,,	,,	23·2
27·195	27·20	27·0	2	,,	,,	24·5
		26·7	1	,,	,,	

* Rowland and Tatnall: 3055·039, 3048·900, 3048·603, 3045·828, 3042·944, 3042·587, 3040·420, 3038·284, 3034·169, 3033·564.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3025·212			0	0·86	9·5	33046·1
	3024·0	3023·7	1	,,	,,	59·3
	23·05	22·8		0·85	,,	69·7
	22·72	22·5	1	,,	,,	73·4
* 20·989	20·99	20·7	2	,,	,,	93·5
		20·5	1	,,	,,	99·1
20·360			0	,,	,,	33104·4
19·876	19·88	19·6	0	,,	,,	08·9
19·472		19·2	2	,,	,,	20·8
	18·38	18·3 Os	2b	,,	,,	
18·158	18·16		2	,,	,,	23·3
		17·6	2	,,	,,	
17·356	17·36	17·32	5	,,	,,	32·1
16·818			0	,,	,,	38·0
	16·10	15·8	2	,,	,,	45·8
	15·60	15·3	2	,,	,,	51·4
		14·5	1	,,	,,	
14·312	14·3	14·3	0	,,	,,	65·6
* 13·477	13·48	13·3	3	,,	,,	74·8
13·172			0	,,	,,	78·0
* 13·040			3	,,	,,	79·6
12·003		12·0	0	,,	,,	91·0
10·623	10·62	10·3	2	,,	,,	33206·2
09·798	09·80		0	,,	,,	15·3
		09·2	1	,,	,,	25·1
* 08·911		08·7	2	,,	,,	27·5
08·695			0	,,	,,	30·9
* 08·387		08·2	2	,,	,,	35·2
	08·00	07·8	1	,,	,,	
		07·2	1	,,	,,	
* 06·708	06·71	06·75	4	,,	,,	49·4
06·094		05·8	2	,,	,,	56·2
		05·1	2	,,	,,	
04·708		04·6	2	,,	,,	71·6
02·600	02·60	02·4	2	,,	,,	94·9
02·188			0	,,	,,	99·5
* 01·756	01·76	01·6	3	,,	,,	33304·3
		01·0	1	,,	,,	
00·341	00·57	00·3	2	,,	,,	17·5
	00·00			,,	,,	
		2999·6	2	,,	,,	34·8
2999·011	2999·01	98·99	1	,,	,,	41·1
* 98·446	98·45	98·2	3	,,	,,	55·0
	98·09	98·0	1	,,	,,	48·9
* 97·743	97·74	97·6	2	,,	,,	53·5
*	97·34	97·4	1	,,	9·6	58·3
* 97·011	96·89	96·6	1	,,	,,	63·4
	96·44	96·2	1	,,	,,	68·1
	96·01	95·8	1	,,	,,	78·4
* 95·083	95·08	94·7	5	,,	,,	84·5
	94·54	94·5	1	,,	,,	
		93·6	1	,,	,,	
* 93·387		93·1	3	,,	,,	97·4

* Rowland and Tatnall: 3020·985, 3013·468, 3013·030, 3008·906, 3008·366, 3006·699, 3001·751, 2998·458, 2997·730, 2997·536, 2997·006, 2995·077, 2993·385.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2993·070			1	0·85	9·6	33400·9
	2992·48	2992·5	1	,,	,,	07·5
92·080	92·08	92·0	0	,,	,,	12·0
	91·71	91·66	8	,,	,,	16·2
90·413			2	,,	,,	30·5
		90·0	1n	,,	,,	
* 89·770		89·4	2	,,	,,	37·9
89·451			2	,,	,,	40·4
* 89·079	89·06	89·02	0	,,	,,	45·5
88·224		88·0	1	,,	,,	55·1
88·047			1	,,	,,	57·1
86·453	86·45	86·5	1	,,	,,	74·9
86·104			0	,,	,,	78·8
	85·78	85·5	1	,,	,,	82·5
	85·08	84·7	1	,,	,,	90·3
	83·74			,,	,,	
* 82·045	82·05	82·0	4	0·84	,,	33524·4
81·080	81·08	80·8	0	,,	,,	35·3
* 80·065	80·07	80·05	3	,,	,,	46·7
* 79·847	79·85	79·80	3	,,	,,	49·2
78·760	78·76	78·72	2	,,	,,	61·4
77·596	77·60	77·4	0	,,	,,	74·5
77·346	77·35	77·25	2	,,	,,	77·4
* 77·048		76·8	3	,,	,,	80·8
* 76·707	76·71	76·62	4	,,	,,	84·6
75·253			1	,,	,,	33601·0
	74·79	74·7	1	,,	,,	06·2
* 74·454	74·45	74·4	2	,,	,,	10·0
* 74·099			3	,,	,,	14·0
73·743	73·74	73·7	0	,,	,,	18·1
		73·3	1	,,	,,	
	73·08	73·0	2	,,	,,	25·5
72·594	72·59	72·4	0	,,	,,	31·1
	71·10	70·9	1	,,	,,	48·0
		70·6	1	,,	,,	
		70·5	1	,,	,,	
69·850	69·85		0	,,	9·7	62·0
69·069	69·07	68·8	4	,,	,,	70·9
68·564	68·56		4	,,	,,	76·6
68·233	68·11	67·9	0	,,	,,	80·4
67·456			2	,,	,,	91·2
	66·98			,,	,,	
66·674	66·67	66·3	1	,,	,,	98·1
65·820		65·72	1	,,	,,	33707·8
65·674	65·67		3	,,	,,	09·4
65 286	65·29	65·2	4	,,	,,	13·9
64·415			0	,,	,,	23·7
63·829			3	,,	,,	30·4
63·523	63·52	63·50	2	,,	,,	33·9
62·705			0	,,	,,	43·2
62·442			0	,,	,,	46·2
61·803	{ 62·08	62·0	2n	,,	,,	60·3
	{ 61·60			,,	,,	

* Rowland and Tatnall: 2989·768, 2989·061, 2982·048, 2980·056, 2979·834, 2977·037, 2976·700, 2974·457, 2974·095.

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2961·097			3	0·84	9·7	33761·6
	2960·35	2960·2	2	,,	,,	70·1
59·855	59·86	59·6	2	,,	,,	75·7
58·993			0	,,	,,	85·6
58·118			3	,,	,,	95·5
57·297			0	,,	,,	33805·0
55·960			0	,,	,,	20·3
55·714			0	,,	,,	23·0
55·463			2	,,	,,	25·9
		55·0	1	,,	,,	
54·594	54·59	54·7	4	,,	,,	35·8
		54·4	2	,,	,,	
54·371	54·20	54·0	0	,,	,,	38·5
53·116			0	,,	,,	52·7
	52·78	52·6	1	,,	,,	56·6
52·599			2	,,	,,	58·7
	52·36	52·2	2	,,	,,	61·3
51·516		51·3	2	,,	,,	71·2
50·650		50·5	1	,,	,,	81·1
50·080	50·08	50·0	0	,,	,,	87·5
49·612	49·61	49·5	4	,,	,,	93·0
		49·2	1	,,	,,	
		48·7	1	,,	,,	
	48·47	48·2	1	,,	,,	33906·1
	47·72	47·7	1	,,	,,	14·8
47·102	47·10	47·0	4	,,	,,	21·9
46·670			0	,,	,,	26·3
45·775	45·78	45·82	4	,,	,,	37·2
45·591			0	,,	9·8	39·2
	45·20	45·0	2	,,	,,	43·7
44·294			0	,,	,,	54·2
44·035	44·04	43·9	3	,,	,,	57·1
43·593	43·59		1	,,	,,	62·3
42·823			0	0·83	,,	71·2
42·366	42·37	42·40	1	,,	,,	76·4
		41·6	1	,,	,,	
		41·0	1n	,,	,,	
40·474		40·3	3	,,	,,	98·3
40·057		39·8	3	,,	,,	34003·1
39·796			0	,,	,,	06·2
39·247	39·25	39·0	2	,,	,,	12·5
37·679			0	,,	,,	30·7
37·448			1	,,	,,	33·3
	37·20	37·0	1	,,	,,	36·2
36·591			0	,,	,,	43·3
36·380			0	,,	,,	45·7
36·131			2	,,	,,	47·8
	35·67	35·5	2	,,	,,	54·0
34·638			0	,,	,,	65·9
34·309			2	,,	,,	69·7
33·367	33·37	33·38	0	,,	,,	80·7
		32·6	1	,,	,,	
	31·35	31·2	2	,,	,,	34104·1
	29·87	29·6	1	,,	,,	21·7
29·027	29·03	29·1	0	,,	,,	31·1
28·608	28·61	28·5	2	,,	,,	36·1

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
	2928·27			0·83	9·8	34140·1
2927·858	27·73	2927·72	0	,,	,,	44·3
27·232			2	,,	,,	52·2
26·913			0	,,	,,	55·9
	26·69	26·5	1	,,	,,	58·5
25·890	25·89		0	,,	,,	67·8
25·685		25·5	0	,,	,,	70·2
25·189			0	,,	,,	76·0
24·760			0	,,	,,	81·0
	24·20	23·9	2	,,	,,	87·5
	23·40	23·1	1	,,	,,	96·9
	22·50	22·3	2	,,	,,	34207·4
	21·95	21·8	1	,,	9·9	19·0
21·276			0	,,	,,	21·7
21·068	21·07		2	,,	,,	24·1
		20·5	1	,,	,,	
20·369			1	,,	,,	32·3
19·723	19·73	19·6	4	,,	,,	39·9
19·276			0	,,	,,	45·1
	18·76	18·5	2	,,	,,	51·2
17·880	17·88	17·9	2	,,	,,	61·6
		17·5	1	,,	,,	
17·353			0	,,	,,	67·6
17·249			2	,,	,,	68·9
16·351	16·47	16·48	6	,,	,,	79·1
15·736			2	,,	,,	86·7
14·403		14·3	2	,,	,,	34302·4
	14·10	14·0	2	,,	,,	06·0
		13·5	1	,,	,,	
13·286	13·29	13·3	3	,,	,,	15·6
		13·0	1	,,	,,	
12·866			0	,,	,,	20·5
12·555	12·56		0	,,	,,	24·2
12·451	12·45		0	,,	,,	25·4
10·542			2	,,	,,	48·0
	10·10			,,	,,	
09·352	09·35	09·95	1	,,	,,	64·0
		09·5	1	,,	,,	
		09·1 Os ?	2	,,	,,	
08·590			0	,,	,,	71·0
		08·0	1n	,,	,,	
		07·1	1n	,,	,,	
		06·6	1	,,	,,	
06·424	06·42	06·3	3	,,	,,	96·6
05·952		05·9	1	,,	,,	34402·2
05·756	05·76		3	,,	,,	04·5
04·825		04·7	0	,,	,,	15·6
		03·7	1	,,	,,	
		03·3	1	,,	,,	
03·180		03·0	2	,,	,,	34·9
02·969		02·8	1	,,	,,	37·6
02·223	02·22	02·10	1	,,	,,	46·4
01·890	01·74	01·8	1	,,	,,	50·4
	00·63	00·7	2	,,	,,	65·4
		99·9	1	,,	,,	
2899·820	2899·70	2899·7	1	,,	,,	75·0

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}$−	Oscillation Frequency in Vacuo
2898·845		2898·7	1	0·83	9·9	34486·6
98·650		98·5	3	,,	,,	88·9
	2898·40			,,	,,	
		98·0	2	,,	,,	
97·820	97·82		1	,,	10·0	34510·8
96·638		96·7	3	,,	,,	12·8
95·925		95·9	1	,,	,,	21·3
95·554			0	,,	,,	25·7
		94·0	1	,,	,,	
93·844	93·84		0	,,	,,	46·1
		92·8	2	,,	,,	
92·654	92·65	92·5	4	,,	,,	60·4
		92·2	1	,,	,,	
	92·00	91·9	1	,,	,,	68·1
91·762		91·5	2	,,	,,	71·0
91·242	91·24		2	,,	,,	77·1
		90·7	1	,,	,,	
		89·9	1n	,,	,,	
		89·6	1	,,	,,	
89·543	89·54		0	,,	,,	97·5
88·739		88·8	2	0·82	,,	34607·2
88·112	88·11	88·2	2	,,	,,	14·7
87·224	87·22	87·3	0	,,	,,	25·3
86·646	86·64	86·7	4	,,	,,	32·3
	85·60	85·6	1	,,	,,	44·8
		85·1	1	,,	,,	
84·601	84·60	84·7	2	,,	,,	56·8
83·701	83·70	83·8	3	,,	,,	67·6
		83·3	1	,,	,,	
82·697			2	,,	,,	79·7
82·222	82·22	82·24	2	,,	,,	85·4
81·373	81·37	81·5	1	,,	,,	95·7
		81·0	1	,,	,,	
80·637	80·64	80·6	0	,,	,,	34704·5
	80·24	80·3	2	,,	,,	09·3
79·853		80·0	3	,,	,,	14·0
79·466			0	,,	,,	18·7
	79·20	79·3	2	,,	,,	21·8
		78·3 Pd	1	,,	,,	
77·930	78·04	78·1	2	,,	,,	37·2
		77·5	1	,,	,,	
77·197		77·3	2	,,	,,	46·0
		76·9	1	,,	,,	
		76·6	1	,,	,,	
		76·3	1	,,	,,	
		75·8	1	,,	,,	
		75·5	1	,,	,,	
75·104	75·10	75·2	5n	,,	,,	71·4
		74·7	1	,,	,,	
74·161			2	,,	,,	82·8
	73·83	73·9	2	,,	,,	86·8
	73·34	73·5	2	,,	,,	92·7
72·468		72·5	2	,,	,,	34803·2
71·756		71·8	4	,,	10·1	11·9
	71·57	71·7	2	,,	,,	14·0
71·296			3	,,	,,	17·3

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		2870·8	2	0·82	10·1	
	2870·53	70·6	1n	,,	,,	34826·8
2870·322			2	,,	,,	29·2
69·047	69·05	69·1	0	,,	,,	44·8
68·662			0	,,	,,	49·3
68·426	68·43	68·5	2	,,	,,	52·2
68·286			2	,,	,,	53·9
	67·20	67·3	1	,,	,,	67·1
66·743	66·74	66·9	5	,,	,,	72·7
	66·41	66·6	2	,,	,,	76·7
	66·19	66·4	2	,,	,,	79·4
	65·65	65·7	2	,,	,,	86·0
64·726			0	0·81	,,	97·2
	63·33	63·5	2	,,	,,	34914·2
63·112		63·1	2	,,	,,	16·8
62·963	62·96		0	,,	,,	22·8
		62·5	1n	,,	,,	
61·833		62·0	1	,,	,,	32·5
61·508	61·54	61·6	5	,,	,,	36·5
	61·17	61·3	1	,,	,,	40·6
	60·95	61·1	1	,,	,,	43·3
60·491	60·49		0	,,	,,	48·9
60·114	60·11	60·2	4	,,	,,	53·5
		60·0	2	,,	,,	
		59·9	2	,,	,,	
	59·65	59·6	1n	,,	,,	
58·693	58·69	59·1	0	,,	,,	68·8
		58·0	2	,,	,,	
	57·88			,,	,,	
57·770			0	,,	,,	82·2
57·367	57·37	57·4	1	,,	,,	87·2
	56·67	56·7	2	,,	,,	95·7
		56·3	1	,,	,,	
56·153		56·1	2	,,	,,	35002·0
55·995		55·9	2	,,	,,	04·0
55·454	55·45	55·5	0	,,	,,	10·6
	55·01	55·1	1	,,	,,	16·1
54·820	54·82	54·9	0	,,	,,	18·4
54·465		54·3	0	,,	,,	22·8
54·173	54·17		4	,,	,,	26·3
53·433	53·43		0	,,	,,	35·4
	53·28	53·3	2	,,	,,	37·3
		52·7	1	,,	,,	
		52·4	1	,,	,,	
51·225			1	,,	,,	62·5
	50·86	50·8	2	,,	,,	67·0
		50·3	1n	,,	,,	
	49·73	49·7	2	,,	,,	82·2
49·399	49·40	49·4	0	,,	,,	85·0
48·688		48·8	1	,,	,,	93·8
	47·72	47·8	1	,,	10·2	35105·6
	47·25	47·3	1	,,	,,	11·3
		46·9	1	,,	,,	
46·662		46·7	0	,,	,,	18·6
46·430		46·5	1	,,	,,	21·5
	45·3			,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
	2844·86	2844·9	2	0·81	10·2	35156·4
		43·9	1	,,	,,	
		43·4	1	,,	,,	
2843·277			2	,,	,,	60·4
42·859		43·0	0	,,	,,	65·6
		42·8	1	,,	,,	
42·651			1	,,	,,	68·2
41·777	41·78	41·81	2	,,	,,	79·0
	41·23	41·3	2	,,	,,	85·8
40·657	40·66	40·8	2	,,	,,	92·9
		39·9	1	,,	,,	
	39·52	39·6	1	,,	,,	35207·0
	39·16	39·1	2	,,	,,	11·6
38·729	38·73	38·9	2	,,	,,	16·8
		38·0	1	,,	,,	
37·384	37·28		0	,,	,,	33·5
36·684	36·68	36·7	2	,,	,,	42·2
		36·5	1	,,	,,	
36·254		36·4	2	,,	,,	47·6
	35·77			,,	,,	
	34·52			,,	,,	
34·107		34·2	3	,,	,,	74·3
	33·97	34·0	2	,,	,,	76·0
	33·64			,,	,,	80·1
32·755		32·9	0	,,	,,	81·1
	32·00	32·1	2	,,	,,	35300·5
31·280			0	,,	,,	09·7
30·815		30·8	1	,,	,,	15·3
		30·3	1	,,	,,	
		30·1	1	,,	,,	
		29·6	1	,,	,,	
		29·4	2	,,	,,	
29·253	29·25		2	,,	,,	44·8
27·969	27·97	28·1	4	,,	,,	50·9
27·627	27·63	27·7	0	,,	,,	55·1
	27·19	27·3	1	,,	,,	60·6
	26·81	26·9	2	,,	,,	65·4
		26·7	1	,,	,,	
	26·36	26·4	2	,,	,,	71·0
	25·62	25·6	2	,,	,,	80·3
	25·20	25·3	2	,,	,,	85·5
24·866			0	0·80	,,	89·7
24·004		24·3	0	,,	,,	35400·5
	23·33	23·4	2	,,	10·3	08·8
22·912		22·9	0	,,	,,	14·1
22·659	22·66	22·62	2	,,	,,	17·3
22·371		22·3	0	,,	,,	21·0
22·142			2	,,	,,	23·7
21·504	21·50	21·48	0	,,	,,	31·8
21·279			1	,,	,,	34·5
		20·8	1n	,,	,,	
19·667			0	,,	,,	54·8
19·062		19·2	2	,,	,,	62·4
18·913			0	,,	,,	64·4
18·460	18·46	18·6	4	,,	,,	70·0
	17·74	17·7	2	,,	,,	80·3

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2817·192		2817·3	3	0·80	10·3	35485·9
		16·7	1n	,,	,,	
		15·9	1	,,	,,	
15·410		15·6	0	,,	,,	35508·5
	2815·18	15·2	1	,,	,,	11·4
		14·7	2	,,	,,	
13·807	13·81	13·78	0	,,	,,	28·7
	13·44	13·38	4	,,	,,	33·3
12·925		13·0	2	,,	,,	48·3
		12·9	1	,,	,,	
	12·06	12·2	1	,,	,,	50·8
	11·66	11·8	1	,,	,,	55·9
11·360			0	,,	,,	59·6
10·788	10·79	10·79	0	,,	,,	66·9
10·645	10·65	10·5	3	,,	,,	68·7
10·131	10·13	10·3	4	,,	,,	75·2
08·335		08·5	0	,,	,,	97·9
	07·7	07·7	2	,,	,,	35606·0
	07·34	07·5	2	,,	,,	10·6
06·845	06·85	06·85	0	,,	,,	16·9
		06·5	1n	,,	,,	
	04·94	05·1	2	,,	,,	41·1
		04·0	1	,,	,,	
	03·76	03·7	1	,,	,,	56·1
03·593		03·4	1	,,	,,	58·2
02·907	02·91	03·1	2	,,	,,	66·9
02·260	02·26	02·4	0	,,	,,	75·1
		01·6	1	,,	,,	
		01·2	1	,,	,,	
00·785	00·79	00·7	1	,,	,,	94·0
		00·6	1	,,	,,	
00·243			0	,,	,,	35701·9
	00·03			,,	,,	
	2799·71	2799·7	1	,,	,,	07·7
		99·4	1	,,	,,	
	98·91	99·0	2	,,	10·4	17·8
	97·91	97·9	1	,,	,,	30·6
	97·20	97·3	1	,,	,,	39·6
2796·652	96·65	96·6	0	,,	,,	46·6
	96·10	96·2	1	,,	,,	53·7
		95·7	1	,,	,,	
95·464	95·46	95·6	0	,,	,,	61·8
	94·42	94·4	2	,,	,,	75·2
		93·2	1	,,	,,	
92·746			2	,,	,,	96·7
92·418	92·42	92·4	2	,,	,,	35800·9
91·164	91·16	91·3	0	,,	,,	04·1
90·695			0	,,	,,	23·0
	90·28	90·3	2	,,	,,	28·3
89·720	89·72	89·6	0	,,	,,	35·5
	88·84	88·8	2	,,	,,	46·8
		88·5	1	,,	,,	
87·930	87·93	87·95	3	,,	,,	58·5
	87·35	87·5	2	,,	,,	65·7
	86·50	86·5	1	,,	,,	66·9
	85·90	85·92	4	,,	,,	84·6

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2785·746			1	0·80	10·4	35886·6
	2785·29	2785·3	2	,,	,,	92·4
84·978			0	,,	,,	96·5
84·625	84·62	84·6	0	,,	,,	35901·1
	83·85	83·9	2	0·79	,,	11·1
		83·0	1	,,	,,	
82·305	82·31	82·4	1	,,	,,	21·0
		81·0	2n	,,	,,	
80·858	80·86		2	,,	,,	49·7
		80·5	1	,,	,,	
		80·0	1	,,	,,	
	79·54	79·6	2	,,	,,	66·7
		79·2	2	,,	,,	
79·081	79·08		0	,,	,,	72·6
	78·54	78·48	6	,,	,,	79·7
		78·2	1	,,	,,	
77·629	77·63	77·8	0	,,	,,	82·6
		77·6	2	,,	,,	
		76·5	1	,,	,,	
76·009		75·9	1	,,	,,	36012·5
75·723	75·72	75·70	0	,,	,,	16·2
75·288		75·3	1	,,	,,	21·9
		75·2	1	,,	,,	
74·589		74·7	2	,,	,,	31·0
		74·4	1	,,	,,	
	74·25			,,	,,	
		73·2	1	,,	,,	
73·068		72·9	0	,,	,,	50·8
72·716	72·72		0	,,	,,	55·3
	72·55	72·58	4	,,	,,	57·5
		72·2	1	,,	,,	
	71·99	72·1	1	,,	,,	64·8
	71·59	71·6	1	,,	,,	70·0
	71·15	71·3	2	,,	,,	75·7
70·805		70·9	2	,,	,,	80·2
70·399	70·40	70·5	0	,,	,,	85·5
69·993			0	,,	,,	90·8
69·024	69·02	69·02	4	,,	10·5	36103·2
68·032			0	,,	,,	16·2
	67·66	67·7	1	,,	,,	21·1
		67·5	1	,,	,,	
		67·1	1	,,	,,	
	66·66	66·7	2	,,	,,	34·1
66·323			0	,,	,,	38·5
	66·00	66·1	2	,,	,,	42·8
65·530	65·53	65·55	2	,,	,,	48·8
	65·24	65·25	4	,,	,,	52·7
64·824		65·0	2	,,	,,	58·2
64·005		64·2	1	,,	,,	68·9
63·513	63·53	63·6	4	,,	,,	75·3
63·232		63·3	2	,,	,,	79·0
		62·9	1	,,	,,	
62·400		62·4	2	,,	,,	89·9
	62·17	62·2	1	,,	,,	93·0
	61·60	61·7	1	,,	,,	36201·4
		61·5	1n	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: λ +	Reduction to Vacuum: $\frac{1}{\lambda}$ −	Oscillation Frequency in Vacuo
	2760·88	2760·9	2	0·79	10·5	36209·8
2760·268	60·27	60·2	0	,,	,,	17·8
		59·8	1	,,	,,	
	59·35	59·3	1	,,	,,	29·9
		59·0	2	,,	,,	
		58·5	1	,,	,,	
58·104	58·10	58·0	0	,,	,,	46·3
57·912			1	,,	,,	48·8
		57·5	1	,,	,,	
57·175		57·1	0	,,	,,	58·5
		56·7	1	,,	,,	
		56·6	1	,,	,,	
	56·46	56·5	1	,,	,,	67·9
		56·0	1	,,	,,	
	55·80 Fe	55·9	1	,,	,,	
		55·5	1	,,	,,	
	55·30	55·3	2	,,	,,	83·2
		54·3	1	,,	,,	
53·543	53·54	53·6	2	,,	,,	36306·3
52·868	52·87	52·94	2	,,	,,	15·2
52·548	52·55	52·59	2	,,	,,	19·5
	52·14	52·3	2	,,	,,	24·8
51·698		51·9	0	,,	,,	30·7
		51·6	1	,,	,,	
		51·0	1	,,	,,	
50·452		50·6	0	,,	10·6	47·0
49·923			0	,,	,,	54·1
	49·66	49·7	2	,,	,,	57·5
	49·26	49·4	2	,,	,,	62·8
		49·2	2	,,	,,	
		48·7	1	,,	,,	
		48·3	1n	,,	,,	
	48·03	48·08	4	,,	,,	79·1
	47·62	47·7	1	,,	,,	84·5
46·991	47·00	47·1	0	,,	,,	92·9
	46·75	46·8	2	,,	,,	96·1
46·169	46·17	46·2	0	,,	,,	36403·9
	45·90	45·98	4	,,	,,	07·3
45·343			0	,,	,,	14·7
	45·22	45·22	4	,,	,,	16·3
44·821			0	,,	,,	21·6
44·541	44·54	44·62	2	,,	,,	25·3
44·022	44·02	44·10	2	,,	,,	32·3
	43·57	43·62	4	,,	,,	38·3
		43·3	1n	,,	,,	
		42·6	2	,,	,,	
	42·15	42·2	1	,,	,,	57·1
		41·7	1n	0·78	,,	
		41·5	1	,,	,,	
		41·4	1n	,,	,,	
		40·7	2	,,	,,	
40·327		40·3	1	,,	,,	81·4
40·085			0	,,	,,	84·6
	39·68 Fe	39·8	1n	,,	,,	
39·311	39·40	39·4	4	,,	,,	94·9
		39·1	1	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2738·983		2738·9	0	0·78	10·6	36501·3
		38·3	1	,,	,,	
		38·0	2	,,	,,	
	2737·87	37·8	2	,,	,,	14·1
	37·66			,,	,,	
36·917	36·92	36·98	0	,,	,,	26·9
36·412	36·54	36·6	0	,,	,,	33·8
35·806	35·81	35·9	2	,,	,,	41·7
34·438	34·44	34·44	3	,,	,,	59·9
	33·68	33·7		,,	,,	70·1
33·167		33·2	0	,,	,,	77·0
	32·83	32·8		,,	,,	79·5
		32·5 Ir ?		,,	,,	
32·011		32·1	0	,,	,,	92·5
	31·48	31·5		,,	,,	99·6
31·028		31·1	2	,,	,,	36605·7
	30·79	30·7		,,	,,	08·8
30·416	30·42	30·5	2	,,	,,	13·9
30·115			0	,,	,,	17·9
29·540	29·54	29·5	2	,,	,,	25·6
	29·04	28·9		,,	,,	32·3
	27·74			,,	,,	
		27·4		,,	,,	
27·063	27·06	27·1	0	,,	10·7	58·8
		26·6		,,	,,	
25·549	25·55	25·55	4	,,	,,	79·2
	24·95	24·95		,,	,,	87·2
		24·2		,,	,,	
24·153		24·0		,,	,,	97·9
		23·6		,,	,,	
	23·10	23·3		,,	,,	36712·1
22·903		22·8	0	,,	,,	14·8
22·760	22·76	22·6	3	,,	,,	16·8
22·493			0	,,	,,	20·3
21·937			0	,,	,,	35·4
21·653		21·7	3	,,	,,	31·7
		21·3		,,	,,	
		20·4		,,	,,	
19·838	19·84	19·8	0	,,	,,	56·2
19·610	19·61	19·7	5	,,	,,	59·3
18·919	18·92	19·0	0	,,	,,	68·6
	17·93	18·0		,,	,,	82·0
17·510	17·51	17·45	2	,,	,,	87·7
17·100			0	,,	,,	93·2
		16·8		,,	,,	
	16·23	16·3		,,	,,	36805·0
	16·15			,,	,,	
15·595		15·6	2	,,	,,	13·6
15·326		15·3 Rh	0	,,	,,	17·3
		14·3		,,	,,	
		14·0		,,	,,	
13·824	13·66	13·7	1	,,	,,	37·7
13·272	13·14	13·2	2	,,	,,	45·1
12·967			0	,,	,,	49·3
12·493	12·49	12·43	4	,,	,,	55·7
12·169			0	,,	,,	60·2

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum: Adeney	Spark Spectrum: Exner and Haschek	Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
		2711·9		0·78	10·7	
		11·2		,,	,,	
2710·321	2710·32	10·3	0	,,	,,	36885·3
		10·0		,,	,,	
09·851			0	,,	,,	91·7
09·291	09·29	09·3	2	,,	,,	99·3
09·157		09·1	0	,,	,,	36901·2
08·930		08·7	0	,,	,,	04·2
08·054		08·2	2	,,	,,	16·2
	07·41	07·5	1n	,,	,,	25·0
		07·4	2	,,	,,	
		06·6	1	,,	,,	
		05·6 Rh	1n	,,	,,	
05·416			0	,,	,,	52·2
	04·99	04·9	1n	,,	,,	58·0
	04·65	04·7	2	,,	,,	62·7
	04·31	04·4	1	,,	,,	67·3
03·891		04·0	2	,,	,,	73·1
03·403		03·7	0	,,	,,	79·7
03·221		03·0	0	,,	,,	82·3
02·916	02·92	02·8	4	,,	,,	86·4
01·434		01·5	4	,,	,,	87·0
	01·09	01·2	2	,,	10·8	97·6
00·772	00·77	00·8	0	,,	,,	37015·6
00·578			1	,,	,,	18·3
	00·32	00·3	2	,,	,,	21·8
2699·957		00·0	1	,,	,,	26·8
	2699·42	2699·5	1	,,	,,	34·2
	98·80			0·77	,,	
	98·23			,,	,,	
98·161			0	,,	,,	51·4
			1	,,	,,	
97·595		97·8	0	,,	,,	59·3
		97·4	2	,,	,,	
	97·18			,,	,,	
96·653		96·7	0	,,	,,	72·2
	94·85	94·8	1	,,	,,	97·0
		94·5	1	,,	,,	
	94·25	94·3	1	,,	,,	37105·3
		93·9	1	,,	,,	
93·750	93·75	93·6	0	,,	,,	12·1
93·392	93·39		2	,,	,,	17·1
92·199 ?	92·20	92·08	4	,,	,,	33·5
90·904			0	,,	,,	51·4
90·487	90·49	90·4	1	,,	,,	57·2
	89·51	89·6	1	,,	,,	70·7
88·969	88·97		1	,,	,,	78·2
88·668			1	,,	,,	82·3
88·216	88·22	88·4	1	,,	,,	88·6
87·580	87·58	87·7	1	,,	,,	97·4
87·214	87·21	87·3	1	,,	,,	37202·4
	86·94	87·1	2	,,	,,	06·3
86·375	86·38	86·5	4	,,	,,	14·0
	85·94	86·1	1	,,	,,	20·1
	85·57	85·8	1	,,	,,	25·2
85·242	85·24	85·4	0	,,	,,	29·7

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ+	1/λ −	
2684·540	2684·69	2684·9	0	0·77	10·8	47239·5
84·172		84·3 Rh	1	,,	,,	44·6
83·756			1	,,	,,	50·4
	82·84	82·9	1n	,,	,,	63·1
		81·5	1	,,	,,	
	80·66	80·7	2	,,	,,	93·4
		80·0	1	,,	,,	
79·843		79·7	1	,,	,,	37304·8
	79·54			,,	,,	
78·837	78·84	78·79	4	,,	10·9	18·7
78·267	78·27	78·3	0	,,	,,	27·7
77·967			0	,,	,,	30·9
77·406		77·5	0	,,	,,	38·7
77·057		77·0	0	,,	,,	43·5
	76·86			,,	,,	
76·430		76·4	2	,,	,,	52·3
	76·27			,,	,,	
	75·58	75·7	2	,,	,,	64·2
75·273	75·27	75·2	0	,,	,,	68·4
	74·27	74·4	2	,,	,,	82·5
73·930		73·7	0	,,	,,	87·8
73·691		73·7	2	,,	,,	90·6
73·550			2	,,	,,	92·5
73·089	73·09	73·2	0	,,	,,	99·0
		72·6	2	,,	,,	
72·451	72·45	72·5	0	,,	,,	37407·9
70·813			0	,,	,,	30·9
70·586	70·60	70·7	0	,,	,,	33·9
		69·6	2	,,	,,	
	69·24			,,	,,	
	68·71	68·7	1	,,	,,	60·4
68·421			0	,,	,,	64·5
68·042		68·1	1	,,	,,	69·8
	67·89			,,	,,	
67·479	67·48	67·35	1	,,	,,	77·6
65·803			1	,,	,,	37501·2
65·542	65·54	65·4	0	,,	,,	04·9
65·227		65·1	0	,,	,,	09·4
64·833	64·83		4	,,	,,	14·9
	64·65			,,	,,	
	63·85	63·6	1	,,	,,	28·8
	62·94	63·0	2	,,	,,	41·6
	62·36	62·3	2	,,	,,	50·2
61·937			0	,,	,,	55·7
61·690	61·69	61·64	4	,,	,,	59·2
61·249	61·25	61·20	2	,,	,,	65·4
60·673		60·8	0	,,	,,	71·6
	59·64	59·8	2	,,	,,	88·2
		59·5	1n	,,	,,	
58·862			0	,,	,,	99·2
58·482		58·4	2	,,	,,	37604·6
	58·28			,,	,,	
57·249	57·25	57·3	1	,,	,,	22·0
56·776			1	,,	11·0	28·6
56·641			1	,,	,,	30·5
56·328	56·33	56·35	1	,,	,,	35·0

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2655·292			1	0·77	11·0	37649·6
55·193			0	,,	,,	51·0
54·898	2654·90	2655·1	0	0·76	,,	55·2
54·563		54·7	0	,,	,,	60·0
		54·2	2	,,	,,	
	54·01			,,	,,	
53·776			1	,,	,,	71·2
53·240		53·2	1	,,	,,	78·8
	53·05			,,	,,	
		52·7	1	,,	,,	
52·240		52·3	0	,,	,,	93·0
	52·05			,,	,,	
51·936	51·94	52·0	4	,,	,,	97·3
51·603		51·7 Rh ?	0	,,	,,	37702·0
51·366	51·37	51·5	2	,,	,,	05·4
50·968	50·97		0	,,	,,	11·1
50·693		50·6	0	,,	,,	15·0
50·486	50·49	50·4	1	,,	,,	17·9
	50·21	50·2	1	,,	,,	21·8
50·076			0	,,	,,	23·8
49·608		49·7	2	,,	,,	30·4
48·872	48·87	48·95	2	,,	,,	40·9
48·706			0	,,	,,	43·3
48·535			1	,,	,,	45·7
47·019		48·1	1	,,	,,	53·1
47·394		47·5	2	,,	,,	62·0
		47·0	1	,,	,,	
46·715			0	,,	,,	71·7
46·087	46·09	46·1	2	,,	,,	80·7
		45·3	1	,,	,,	
44·711	44·71	44·7	0	,,	,,	37800·3
44·187			0	,,	,,	08·6
43·600	43·60	43·7	0	,,	,,	16·2
		43·3	2	,,	,,	
43·042	43·04	43·1	4	,,	,,	24·2
42·607		42·5	0	,,	,,	30·4
		42·3	1	,,	,,	
42·063	42·06		0	,,	,,	38·2
	41·72	41·7	2	,,	,,	43·1
41·549			0	,,	,,	45·6
40·413	40·41		2	,,	,,	61·9
	39·67	39·7	2	,,	,,	72·5
39·205		39·3	2	,,	,,	79·4
38·597	38·60	38·6	2	,,	,,	87·9
		38·5	1	,,	,,	
		38·2	1	,,	,,	
	36·95	36·9	1	,,	,,	37911·6
36·760		36·7	2	,,	,,	14·3
36·617	36·62		0	,,	,,	16·4
35·927	35·93	36·0 Pd	4	,,	,,	26·3
35·451	35·45	35·4	0	,,	,,	33·2
	33·93			,,	,,	
		33·7	1	,,	,,	
33·537			0	,,	,,	60·8
	32·85	32·9	2	,,	,,	70·7
32·584		32·5	1	,,	,,	74·5

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2632·210		2632·4	0	0·76	11·0	37979·9
31·657		31·7	1	,,	11·1	87·8
		31·5	1	,,	,,	
	2631·22	31·3	2	,,	,,	94·1
30·314			1	,,	,,	38007·1
	30·19	30·2	2	,,	,,	09·0
30·010			0	,,	,,	11·6
	29·49	29·5	1	,,	,,	19·1
	28·91	28·9	2	,,	,,	27·5
28·621			0	,,	,,	31·6
28·375	28·38	28·3 Pd ?	4	,,	,,	35·2
	27·90			,,	,,	
27·737	27·74		1	,,	,,	44·5
		27·5	1	,,	,,	
	26·60	26·5	2	,,	,,	60·9
26·444			0	,,	,,	63·2
26·290		26·1	0	,,	,,	65·4
	25·95			,,	,,	
	25·59	25·6	1	,,	,,	75·6
		25·5	2	,,	,,	
25·168		25·2	0	,,	,,	81·7
	24·87	24·9	1	,,	,,	86·0
	24·35	24·3	1	,,	,,	93·6
23·914			1	,,	,,	99·9
	23·76	23·7	1n	,,	,,	38102·1
	23·51			,,	,,	
		23·1	1	,,	,,	
		22·9	1	,,	,,	
		22·4	1n	,,	,,	
	21·91	21·9	1	,,	,,	29·0
	21·46	21·4	1	,,	,,	35·6
21·173		21·2	0	,,	,,	39·8
20·713	20·71	20·8	2	,,	,,	46·4
20·154	20·15	20·2	0	,,	,,	54·6
19·745		19·8	2	,,	,,	60·5
	19·42	19·5	2	,,	,,	65·3
19·105		19·2	0	,,	,,	69·8
	18·68			,,	,,	
17·882		18·0	1	,,	,,	87·7
		17·6	1	,,	,,	
	17·29	17·2	2	,,	,,	96·3
	16·50	16·5	1	,,	,,	38207·9
		15·7	1	,,	,,	
15·179	15·18	15·2	2	,,	,,	27·2
	14·93	15·0	2	,,	,,	31·0
14·671		14·8 Pd	2	,,	,,	34·6
14·151	14·15	14·2	1	,,	,,	42·2
		14·0	1n	,,	,,	
	13·37	13·4	1n	,,	,,	53·6
13·143			0	,,	,,	57·0
12·990			0	,,	,,	59·2
	12·63	12·6	2	,,	,,	64·5
12·165	12·17	12·2	2	,,	,,	71·3
	11·99	12·0	1	,,	,,	73·9
	11·63	11·6	2	,,	,,	79·2
11·130		11·2	2	,,	,,	86·5

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
	2610·18	2610·2	2	0·76	11·0	38300·3
2609·573	09·57	09·6	2	0·75	,,	09·5
09·143	09·14	09·2	4	,,	11·2	15·5
		08·5	1	,,	,,	
08·024	08·02	08·0	1	,,	,,	32·0
07·440			0	,,	,,	40·6
	07·18 Fe	07·0	1	,,	,,	
	06·40	06·4	2n	,,	,,	56·8
05·950		06·0	2	,,	,,	62·5
05·439		05·5	2	,,	,,	68·4
04·409	04·41	04·3	0	,,	,,	85·2
	03·43	03·4	1n	,,	,,	99·6
	03·00	03·0	1	,,	,,	38406·0
	02·49	02·4	2	,,	,,	13·5
01·553	01·55	01·6	2	,,	,,	27·3
01·392			0	,,	,,	29·7
00·840		00·7	0	,,	,,	37·9
	00·5			,,	,,	
	00·00	2599·9	1	,,	,,	50·3
	2599·53 Fe	99·6	1	,,	,,	
		99·5	1	,,	,,	
	98·99 Fe	99·0	2	,,	,,	
2598·681	98·68	98·6	0	,,	,,	69·8
	98·07	98·1	2	,,	,,	78·9
	97·84	97·7	1	,,	,,	82·3
97·417	97·42	97·3	1	,,	,,	88·5
96·043	96·04	96·0	0	,,	,,	38508·9
95·734			0	,,	,,	12·5
94·926		95·1	2	,,	,,	25·5
	94·65	94·6	1	,,	,,	29·6
	93·79	93·9	1n	,,	,,	42·4
		93·6	1n	,,	,,	
		93·3	1n	,,	,,	
		93·1	1n	,,	,,	
		92·3	1	,,	,,	
92·093			2	,,	,,	67·6
91·710			0	,,	,,	73·4
	91·44	91·5	2	,,	,,	77·4
91·201	91·20	91·3	2	,,	,,	80·9
91·087			1	,,	,,	82·6
89·886		89·9	0	,,	,,	38600·5
89·649	89·65	89·6	2	,,	,,	04·1
89·129		89·0	0	,,	,,	11·8
	88·08	88·1	1	,,	11·3	27·3
87·413			0	,,	,,	37·3
	86·95	87·0	1n	,,	,,	44·4
86·157	86·16	86·0	0	,,	,,	56·1
85·815			0	,,	,,	61·2
85·412		85·6	1	,,	,,	67·2
84·211		84·4	2	,,	,,	85·2
83·131	83·13	83·2	2	,,	,,	38701·4
		83·1	1	,,	,,	
		82·7	1	,,	,,	
	82·48			,,	,,	
81·990		82·1	2	,,	,,	20·0
		81·6	1	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ+	$\frac{1}{\lambda}$ −	
2581·216	2581·23	2581·3	2	0·75	11·3	38730·1
		81·0	1	,,	,,	
80·883			2	,,	,,	35·1
80·316	80·32	80·4	0	,,	,,	43·6
	80·08			,,	,,	
79·879	79·94	79·8	0	,,	,,	50·2
79·623			2	,,	,,	54·0
79·309		79·3	1	,,	,,	58·7
79·071	79·10		2	,,	,,	62·4
78·653	78·65	78·8	2	,,	,,	68·7
		78·4	1	,,	,,	
		77·5	1	,,	,,	
77·052	77·11	77·2	0	,,	,,	92·7
	76·17	76·3	2	,,	,,	38806·0
		75·7	1n	,,	,,	
75·339			1	,,	,,	18·5
		74·8	1	,,	,,	
	74·20	74·3	1	,,	,,	35·7
73·654	73·65	73·6	0	,,	,,	44·0
		73·3	1	,,	,,	
	73·09	73·0	1	,,	,,	52·5
	72·71	72·7	1n	,,	,,	58·2
72·512			2	,,	,,	61·2
72·370			2	,,	,,	63·3
	71·17	71·3	2	,,	,,	81·4
71·068		70·8	2	,,	,,	83·0
		70·5	1	,,	,,	
70·180		70·0	0	,,	,,	96·4
69·840	69·84	69·8	2	,,	,,	38 01·6
		69·5	1	,,	,,	
	68·93	69·1	2	,,	,,	15·4
68·854			4	,,	,,	16·6
		68·2	1	,,	11·4	
67·981			1	,,	,,	29·7
		67·7	1	,,	,,	
66·666	66·67	66·8	2	,,	,,	49·6
	66·30	66·5	2	,,	,,	55·2
		66·1	1	,,	,,	
	65·77	65·8	2	,,	,,	63·3
		65·5 Pd	1	,,	,,	
65·277			1	,,	,,	70·7
		65·1	1	,,	,,	
64·674	64·73	64·9	1	0·74	,,	79·9
64·503			0	,,	,,	82·5
	64·02	64·2	2	,,	,,	89·9
	63·78	63·8	1	,,	,,	93·5
	63·38	63·5	1	,,	,,	99·6
	63·00	63·2	1	,,	,,	39005·4
	62·58	62·8	1	,,	11·5	11·7
62·252		62·4	2	,,	,,	16·7
		61·7	1	,,	,,	
		61·4	1	,,	,,	
		61·1	1	,,	,,	
60·920		61·0	3	,,	,,	37·0
60·347	60·35	60·5	2	,,	,,	45·7
		60·1	1	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2559·497	2559·60	2559·7	0	0·74	11·5	39058·7
	58·91			,,	,,	
58·626	58·63	58·7	2	,,	,,	72·0
58·359			0	,,	,,	76·1
	58·13	58·2	1	,,	,,	79·6
57·784	57·78	57·9	1	,,	,,	84·8
	57·25	57·3	2	,,	,,	93·0
56·994	56·96	56·9	0	,,	,,	96·9
56·100	56·10	56·2	2	,,	,,	39110·6
55·955	55·96	55·9	2	,,	,,	12·8
55·734			0	,,	,,	16·2
		55·0	1n	,,	,,	
54·790			1	,,	,,	30·7
		54·5	1	,,	,,	
54·060			1	,,	,,	41·9
	53·58	53·6	1n	,,	,,	46·0
52·965			0	,,	,,	63·5
52·524			0	,,	,,	65·4
52·384			0	,,	,,	68·5
52·083	52·08	52·10	0	,,	,,	72·3
51·822	51·82	51·7 Pd	0	,,	,,	76·2
51·466		51·4	1	,,	,,	81·6
50·946			1	,,	,,	89·6
	49·92	50·0	2	,,	,,	39205·4
49·664			2	,,	,,	09·4
49·576		49·6	2	,,	,,	10·7
49·260	49·26	49·3	0	,,	,,	15·6
	48·86	49·0	1	,,	,,	21·7
		48·1	1	,,	,,	
47·600	47·80	47·8	1	,,	,,	41·2
		47·0	2	,,	,,	
46·765	46·81		2	,,	,,	54·0
45·866	46·01	45·8	0	,,	,,	67·8
	45·10	45·1	1n	,,	,,	79·6
44·318	44·32	44·4	2	,,	,,	91·6
43·778			1	,,	,,	39300·1
43·349	43·35	43·38	2	,,	,,	06·7
43·240			0	,,	,,	08·4
42·601			0	,,	,,	18·3
	42·24	42·3	2n	,,	,,	23·8
		41·6	1	,,	,,	
41·381			0	,,	,,	37·1
40·411	40·41	40·43	0	,,	,,	52·2
39·822	39·82	39·90	1	,,	,,	61·3
38·565			0	,,	,,	80·9
		38·1	1n	,,	,,	
37·776	37·78	37·6	0	,,	,,	93·1
	37·18			,,	,,	
	36·90			,,	,,	
	36·51			,,	,,	
36·315			0	,,	,,	39415·7
	35·80	35·7	2	,,	,,	23·8
	35·42	35·5	2	,,	,,	29·7
35·147	35·15	35·1	0	,,	,,	33·9
	34·23	34·2	2	,,	,,	48·2
	33·66	33·6	1	,,	,,	57·1

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ+	$\frac{1}{\lambda}$−	
2533·331	2533·33	2533·3	1	0·74	11·5	39462·2
32·128			1	,,	,,	68·7
	30·67	30·6	2	,,	,,	39503·7
	30·40	30·2	1	,,	,,	07·9
29·812	29·81	29·7	1	,,	11·6	17·0
28·813			0	,,	,,	32·8
28·027	28·03	28·00	0	,,	,,	45·0
	27·19	27·2	1n	,,	,,	58·1
26·914		27·1	2	,,	,,	62·4
26·011			0	,,	,,	76·7
25·726	25·68	25·6 Ir	0	,,	,,	81·0
25·263			0	,,	,,	88·3
	25·12			,,	,,	
24·952	24·95	25·0	0	,,	,,	99·9
		24·6	1	,,	,,	
		23·9	1	,,	,,	
		23·3	1	,,	,,	
	22·83	22·8	1	,,	,,	39626·4
22·410		22·5	0	,,	,,	33·0
21·700		21·9	2	,,	,,	44·2
	21·08	21·0	2	,,	,,	53·9
20·925	20·89	20·8	1	,,	,,	56·4
20·041			0	,,	,,	70·3
	19·49	19·32	4	,,	,,	78·9
18·601	18·60	18·55	0	,,	,,	94·6
17·728			2	,,	,,	39706·7
17·403	17·40	17·38	2	,,	,,	11·9
	17·00			,,	,,	
16·882		16·9	0	,,	,,	20·1
	16·25	16·2	1n	,,	,,	30·0
	15·74	15·8	1	,,	,,	38·1
15·372		15·5	1	,,	,,	43·9
	14·10	14·3	1n	,,	,,	64·1
13·417	13·42	13·40	2	,,	,,	74·9
12·898		13·0	2	,,	,,	83·1
	12·79	12·7	1	,,	,,	84·8
11·652		11·7	1	,,	11·7	39802·7
	11·41	11·4	1n	,,	,,	04·9
11·058			0	,,	,,	12·1
10·238			0	,,	,,	25·2
09·709		09·6	0	,,	,,	33·6
09·160		09·2	1	0·73	,,	42·3
08·508	08·81	08·80	2	,,	,,	52·6
08·377		08·4	2	,,	,,	54·8
07·090	07·13	07·16	2	,,	,,	75·1
	06·61	06·6	2	,,	,,	82·7
		06·5	2	,,	,,	
	06·18	06·1	1	,,	,,	91·2
	05·73	05·8 Pd	1	,,	,,	96·8
		05·5	1	,,	,,	
	05·13	05·1	1	,,	,,	39906·3
	03·40	03·4	1	,,	,,	34·0
02·966		03·0	0	,,	,,	40·9
02·484	02·48	02·5	0	,,	,,	48·5
01·990	02·12	02·1	0	,,	,,	56·5
01·569		01·7	2	,,	,,	61·2

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrun	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2500·940			0	0·73	11·7	39973·3
00·484	2500·36	2500·3	0	,,	,,	80·5
2499·873		2499·9	2	,,	,,	90·3
	2499·60	99·5	1	,,	,,	94·7
		99·2	1	,,	,,	
98·670	98·67	98·7 Pd	2	,,	,,	40009·6
98·512		98·6	2	,,	,,	12·1
		98·1	1	,,	,,	
	97·14	97·0	1	,,	,,	34·1
95·775	95·88	95·8	2	,,	,,	56·0
94·773	94·77	94·6	1	,,	,,	73·6
	94·22	94·3	1	,,	,,	81·0
94·116	94·00	93·80	2	,,	11·8	82·7
		92·9	1	,,	,,	
		92·3	1	,,	,,	
		92·1	1	,,	,,	
91·847	91·85	91·6	2	,,	,,	40119·1
		91·4	1	,,	,,	
	91·10	91·2	2	,,	,,	31·1
90·555		90·7	0	,,	,,	39·9
90·017			2	,,	,,	48·6
	89·34	89·5	2	,,	,,	59·5
	88·58	88·7 Pd	2	,,	,,	71·8
		88·3	1	,,	,,	
		88·1	1	,,	,,	
		87·7	1	,,	,,	
	87·26	87·3	1	,,	,,	93·1
		86·7 Pd	1n	,,	,,	
	86·31	86·3	1	,,	,,	40208·5
	84·66			,,	,,	
84·055	84·06	84·2	0	,,	,,	45·0
	83·82	83·7	1	,,	,,	47·8
		83·3	1	,,	,,	
		83·0	2	,,	,,	
82·628			0	,,	,,	68·1
		82·0	1	,,	,,	81·0
	81·83			,,	,,	
81·216	81·22	81·30	0	,,	,,	91·0
	80·83	81·0	2	,,	,,	97·3
		80·3	1	,,	,,	
79·611			0	,,	,,	40317·1
79·458			0	,,	,,	19·6
79·010	79·01	79·02	2	,,	,,	26·9
	78·33	78·5	2	,,	,,	38·0
		78·2	1	,,	,,	
	77·22	77·4	2	,,	,,	56·1
		77·1	1	,,	,,	
76·960		76·6	2	,,	11·9	60·3
76·395		76·4	0	,,	,,	69·2
75·483			2	,,	,,	84·4
		75·0	2	,,	,,	
74·506	74·55		0	,,	,,	40400·2
74·115		74·2	1	,,	,,	06·6
	73·55	73·8	1	,,	,,	15·8
	72·81	73·0	2	,,	,,	27·9
72·215	72·22	72·6	0	,,	,,	37·6

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda+$	$\frac{1}{\lambda}-$	
2471·576		2471·8	0	0·73	11·9	40448·1
		71·3	1	,,	,,	
70·805			0	,,	,,	60·7
70·608	2470·61	70·7	0	,,	,,	64·0
	69·78			0·72	,,	
		68·8	1	,,	,,	
		68·5	1	,,	,,	
67·674	67·67	67·7	0	,,	,,	40512·1
		67·5	1	,,	,,	
		67·3	1	,,	,,	
		66·4	1n	,,	,,	
		65·7	1	,,	,,	
		65·5	1	,,	,,	
		65·1	1	,,	,,	
64·781	64·78	64·9	2	,,	,,	59·7
64·474			0	,,	,,	64·7
		64·0	1	,,	,,	
63·026	63·03	63·1	2	,,	,,	88·6
		62·8	1	,,	,,	
	62·20	62·3	1	,,	,,	40603·2
61·506		61·7	0	,,	,,	13·7
		61·5	1	,,	,,	
	60·57			,,	,,	
	60·17	60·1	1	,,	,,	35·7
		59·6	1	,,	,,	
		59·4	1	,,	,,	
59·146	59·15		0	,,	12·0	42·6
58·706		58·8 Rh	2	,,	,,	59·8
57·311	57·31	57·4	0	,,	,,	82·9
57·050			1	,,	,,	87·2
56·666		56·70	4	,,	,,	93·6
56·519	56·59	56·60	4	,,	,,	96·0
56·376			0	,,	,,	98·3
55·614	55·61	55·66	5	,,	,,	40712·0
55·005		54·9	2	,,	,,	21·2
54·267	54·27	54·4	0	,,	,,	33·6
	53·85	54·0	2	,,	,,	40·3
		52·6	1n	,,	,,	
	51·27	51·4	2	,,	,,	83·2
		51·1	2	,,	,,	
50·650	50·90	50·7	1	,,	,,	93·5
50·464	50·46	50·6	0	,,	,,	96·7
49·958			1	,,	,,	40805·0
		49·6		,,	,,	
48·958	48·96	49·0	0	,,	,,	28·0
		48·4	1	,,	,,	
47·537		47·6	1n	,,	,,	45·4
		46·9	1	,,	,,	
		46·7	1	,,	,,	
45·519	45·52		0	,,	,,	79·1
44·924			0	,,	,,	89·1
44·497		44·5	0	,,	,,	96·2
44·129		44·2	1	,,	,,	40902·4
	43·48	43·4	2n	,,	12·1	13·2
43·036			0	,,	,,	21·6
	41·82	41·6	1	,,	,,	41·0

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
2441·419	2441·42	2441·4	0	0·72	12·1	40947·7
41·051	41·05	40·9	1	,,	,,	53·9
39·715	39·72	39·7	0	,,	,,	76·3
		39·3	1	,,	,,	
		39·0	1	,,	,,	
		38·8	1	,,	,,	
		38·5	1	,,	,,	
		37·3	1	,,	,,	
37·019		37·1	0	,,	,,	41021·7
		36·6	1	,,	,,	
		36·3	1	,,	,,	
	35·53	35·62	4	,,	,,	46·8
34·980	34·98	35·1	0	,,	,,	65·9
	33·81	34·0	1n	,,	,,	75·7
		33·2	1n	,,	,,	
		33·0	1	,,	,,	
	32·25	32·3	2	,,	,,	41102·1
		31·6	1	,,	,,	
		30·8	1	,,	,,	
	30·45	30·5	2	,,	,,	32·6
29·672		29·6	2	,,	,,	45·7
		29·4	1	,,	,,	
		29·1	1	,,	,,	
	28·98	29·0	1	,,	,,	57·5
	27·82	27·8	2	,,	12·2	77·0
	27·26	27·2	1	,,	,,	86·5
	26·96			,,	,,	91·6
	26·66	26·7	1	,,	,,	96·7
		26·0	1n	,,	,,	
		25·7	1n	,,	,,	
	24·56	24·6	1	,,	,,	41232·5
		23·7	1n	,,	,,	
	22·91	23·0	2	,,	,,	60·5
	22·30	22·4	2	,,	,,	70·9
		21·4	1	0·71	,,	
20·905		20·9	2	,,	,,	94·7
	20·24	20·3	1	,,	,,	41306·0
		20·2	1	,,	,,	
		20·0	1	,,	,,	
	19·04	19·1	1	,,	,,	27·5
		18·6	1	,,	,,	
		18·3	1	,,	,,	
	17·05	17·1	2	,,	,,	60·6
	16·64			,,	,,	
	15·82	15·8	2	,,	,,	81·6
	15·30	15·4	2	,,	,,	90·5
	14·93	14·9	2	,,	,,	96·9
	14·00	14·0	2	,,	,,	41412·8
	13·60	13·5	2	,,	,,	19·6
	13·32			,,	,,	
		12·9	1	,,	,,	
		12·6	1	,,	,,	
		12·1	1	,,	,,	
	11·62	11·7	1	,,	12·3	53·6
		11·5	1	,,	,,	
		11·2	1	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
		2410·8	1	0·71	12·3	
	2410·24	10·3	2	,,	,,	41477·3
		10·0	1	,,	,,	
		09·7	1	,,	,,	
2408·744		08·7	1	,,	,,	41503·1
	08·51			,,	,,	
07·997	08·00		2	,,	,,	16·0
	07·37	07·6	1	,,	,,	26·8
		07·1	1	,,	,,	
	06·67	06·9	1	,,	,,	38·9
	06·12			,,	,,	
		05·5	1	,,	,,	
		05·4	1	,,	,,	
	05·00	05·1	1	,,	,,	67·7
		04·9	1	,,	,,	
		04·6	1	,,	,,	
02·802	02·80	02·90	4	,,	,,	41605·8
	01·93			,,	,,	
	01·18	01·3	1	,,	,,	33·8
		00·7	1n	,,	,,	
	00·38	00·3	1	,,	,,	47·8
	2399·28			,,	,,	
	98·63			,,	,,	
		2398·0	2	,,	,,	
	97 70	97·2	2	,,	12·4	99·7
2396·791	96·79	96·90	2	,,	,,	41710·0
		96·0	1n	,,	,,	
	95·66	95·6	1	,,	,,	29·7
		95·3	1	,,	,,	
		95·0	1	,,	,,	
	94·70			,,	,,	
		94·2	2	,,	,,	
	93·84	93·7	1	,,	,,	61·5
		93·3	1	,,	,,	
92·501		92·7	2	,,	,,	84·9
		92·1	2	,,	,,	
	91·73	91·8	1	,,	,,	98·3
		91·4	1	,,	,,	
		90·6	1	,,	,,	
		90·4	1	,,	,,	
		90·1	1	,,	,,	
		88·5	1	,,	,,	
		88·3	1n	,,	,,	
	87·28			,,	,,	
		84·3	1	,,	,,	
	83·53	83·7	2	,,	,,	41942·2
		83·0	1	,,	,,	
	82·08	82·18	4	,,	12·5	67·6
		81·5	1	,,	,,	
		81·2	1	,,	,,	
		81·0	1	,,	,,	
		80·8	1	,,	,,	
		80·1	2	,,	,,	
	79·94	79·9	2	,,	,,	42002·4
	79·54			,,	,,	
		77·6	1n	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
	2376·30	2376·6	2	0·71	12·5	42069·7
	75·71	75·80	4	,,	,,	80·2
		75·6	1	,,	,,	
2375·346		75·3	2	,,	,,	86·6
		75·1	1	,,	,,	
		74·3	1	,,	,,	
	72·08	72·2	2	0·70	,,	42144·6
70·251	70·25	70·4	2	,,	,,	77·1
		70·2	1	,,	,,	
		68·7	1n	,,	,,	
		68·2 Ir	1	,,	,,	
	67·31	67·5	2	,,	12·6	42229·4
		64·6	1	,,	,,	
	64·13	64·3	1n	,,	,,	86·3
		63·7	1n	,,	,,	
		62·9	1	,,	,,	
	62·47	62·7	1	,,	,,	42316·0
		62·3	1	,,	,,	
		60·8	1n	,,	,,	
	59·14	59·3	2	,,	,,	71·7
	58·90	58·95	4	,,	,,	80·0
57·991	57·99	58·10	2	,,	,,	96·2
	52·92	53·2	2	,,	12·7	42487·7
51·411		51·6	2	,,	,,	42515·0
	51·23	51·3	1	,,	,,	18·2
	50·51	50·7	1	,,	,,	31·3
	46·45	46·6	1	,,	,,	42604·9
		44·7	1	,,	,,	
		43·6	1	,,	,,	
42·920	42·92	43·03	2	,,	,,	69·1
	42·66	42·7	2	,,	,,	75·6
	41·11			,,	,,	
40·767	40·77	40·8	2	,,	12·8	42708·2
	40·00	40·2	1	,,	,,	22·2
		39·4	1	,,	,,	
		38·9	1	,,	,,	
38·094	38·05	38·1	2	,,	,,	57·1
	36·93	37·0	2	,,	,,	78·4
		36·1	1	,,	,,	
35·047	35·05		2	,,	,,	42812·9
		34·5	1	,,	,,	
	34·05	34·1	2	,,	,,	31·2
	33·72	33·8	2	,,	,,	37·2
	32·26	32·5	1n	,,	,,	64·0
	31·81	31·9	1	,,	,,	72·3
	31·23	31·3	2	,,	,,	83·0
	29·11	29·2	2	,,	,,	42922·0
		28·5	1	,,	,,	
		28·1	1	,,	,,	
	20·82			0·69	,,	
		20·0	2	,,	,,	
		18·7	1	,,	,,	
	13·51	13·6	1	,,	13·0	43210·4
		09·3	1	,,	,,	
		08·8	1	,,	,,	
		08·6	1	,,	,,	

RUTHENIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Spark Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
	Adeney	Exner and Haschek		λ +	$\frac{1}{\lambda}$ −	
		2308·1	1n	0·69	13·0	
	2305·85	05·7	2	,,	,,	43356·0
	04·97			,,	,,	
	03·06			,,	,,	
	2298·80	2298·7	1	,,	13·1	87·9
	97·28	97·5	1	,,	,,	43416·6
		94·6	1	,,	,,	
		94·2	1	,,	,,	
	87·2	87·2	2	,,	13·2	43708·4
		83·2	1	,,	,,	
	82 00	81·8	2	,,	,,	43808·0
		81·7	1	,,	,,	
		79·7	1	,,	,,	
		79·4	1n	,,	,,	
		78·7	1n	,,	,,	
		72·3	1n	0·68	,,	
	68·26	68·3	1	,,	13·3	44073·4
	63·73	63·6	1	,,	,,	44161·6
		61·1	1	,,	,,	
		51·7	1	,,	,,	

YTTRIUM.

Lohse, 'Sitzber. kaiserl. Akad. Wissensch. Berlin,' xii. 1897.
Exner and Haschek, 'Sitzber. kaiserl. Akad. Wissensch. Wien,' cviii. 1899.
Kayser, 'Abhandl. königl. Akad. Wissensch. Berlin,' 1903.

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	$\frac{1}{\lambda}$ −	
6701·188	2			1·82	4·0	14918·7
6687·892	2			,,	,,	50·6
56·056	1			1·81	4·1	15019·8
50·880	1			,,	,,	33·9
13·988	1			1·80	,,	15115·4
6585·077	1			1·79	,,	81·7
77·096	1			,,	,,	15200·2
64·059	1			1·78	,,	30·4
57·568	2			,,	,,	45·4
38·797	3			,,	,,	89·2
05·611	1			1·77	4·2	15367·1
6437·414	1			1·75	,,	15530·0
35·226	5			,,	,,	35·3
02·229	3			1·74	,,	15615·4
6396·588	1			,,	,,	29·1
6275·214	1			1·71	4·3	15931·4
36·962	b			1·70	,,	16029·2
22·787	4			1·69	4·4	65·6
18·150	b			,,	,,	77·5
00·043	b			,,	,,	16124·7
6191·930	1			1·68	,,	45·7

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
6182·455	b			1·68	4·4	16170·4
65·310	b			,,	,,	16215·4
50·935	1			1·67	,,	53·3
48·624	b			,,	,,	59·4
38·645	4			,,	,,	85·9
37·893	1			,,	,,	87·8
34·240	3			,,	,,	97·5
32·343	b			,,	,,	16312·6
27·610	1			,,	,,	15·2
24·701	1			,,	,,	22·9
14·954	1			,,	,,	49·0
08·050	1			1·66	,,	67·4
02·967	1			,,	,,	81·1
6096·999	1			,,	,,	97·1
89·597	1			,,	,,	16417·0
88·190	2			,,	4·5	20·7
82·800	1			,,	,,	35·3
81·448	1			,,	,,	39·0
73·034	1			1·65	,,	59·3
60·526	1			,,	,,	95·7
53·998	b			,,	,,	16513·5
42·778	1			1·64	,,	44·2
40·463	2			,,	,,	40·5
36·833	b			,,	,,	60·5
25·513	1			,,	,,	91·6
23·624	2			,,	,,	96·8
20·105	b			,,	,,	16606·5
08·424	2			,,	,,	37·8
07·929	1			,,	,,	40·2
04·906	1			1·63	,,	48·6
03·810	b			,,	,,	51·6
5987·870	b			,,	,,	93·1
82·133	2			,,	,,	16711·9
72·324	b			,,	,,	39·4
66·439	1			1·62	,,	55·9
50·249	2			,,	4·6	16801·4
45·946	3			,,	,,	13·6
45·081	1			,,	,,	16·0
03·201	2			1·61	,,	16935·3
5880·218	1			1·60	,,	17001·5
72·072	1			,,	4·7	25·2
32·480	1			1·59	,,	17138·7
22·064	2			,,	,,	75·4
12·888	1			1·58	,,	98·6
5797·348	1			,,	,,	17244·6
87·907	1			,,	,,	72·7
81·901	2			,,	,,	90·6
74·143	2			1·57	,,	17313·9
65·849	3			,,	,,	42·9
44·046	3			,,	,,	17404·5
43·567	1			,,	,,	06·1
40·417	1			1·56	,,	15·6
29·087	3			,,	,,	50·1
27·090	1			,,	,,	56·2
23·663	2			,,	,,	66·6
20·801	3			,,	4·8	75·3

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum $\lambda +$	$\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
5706·926	5			1·56	4·8	17517·9
5675·480	3			1·55	,,	17614·8
75·311	2			,,	,,	15·3
69·456	1			,,	,,	33·6
68·784	1			,,	,,	35·7
* 63·148	6			1·54	,,	53·2
61·107	1			,,	,,	59·6
57·479	1			,,	,,	70·9
48·684	5			,,	,,	98·4
46·909	2			,,	,,	17704·1
44·898	4			,,	,,	10·3
35·966	1			,,	,,	38·4
33·121	2			,,	,,	47·3
32·477	2			,,	,,	49·4
30·353	5			,,	,,	56·1
24·114	2			,,	,,	75·8
10·580	1			1·53	,,	17818·7
06·552	3			,,	4·9	31·4
5598·537	1			,,	,,	56·9
91·168	2			,,	,,	80·4
82·098	5			1·52	,,	17909·5
81·295	2			,,	,,	12·1
77·621	4			,,	,,	23·9
67·972	3			,,	,,	55·0
56·655	4			,,	,,	91·5
51·209	2			1·51	,,	18009·3
46·228	4			,,	,,	25·4
* 44·818	5			,,	,,	30·0
41·852	3			,,	,,	39·6
27·765	6			,,	,,	85·6
25·944	2			,,	,,	88·3
21·845	6r			,,	,,	18105·0
13·856	2			1·50	,,	31·2
* 10·115	5			,,	,,	43·5
03·665	5			,,	5·0	64·7
5497·637	5			,,	,,	84·6
95·802	2			,,	,,	90·7
93·375	3			,,	,,	98·7
91·634	2			,,	,,	18204·5
80·952	3			,,	,,	40·0
73·596	4			1·49	,,	64·5
66·669	6			,,	,,	87·7
38·447	4			1·48	,,	18382·6
24·588	3			,,	,,	18429·5
17·246	2			,,	,,	54·6
* 03·003	4			,,	,,	18503·2
5388·623	1			1·47	5·1	52·5
80·851	3			,,	,,	83·9
5290·004	2			1·45	5·2	18898·4
70·527	3			1·44	,,	18968·2
69·712	5			,,	,,	71·2
40·958	2			1·43	,,	19075·3
* 05·890	6			1·42	5·3	19203·7
00·580	5			,,	,,	23·3

* Rowland: 5663·155, 5544·831, 5510·120, 5402·982, 5205·897.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	1/λ −	
5196·588	2			1·42	5·3	19238·1
35·356	3			1·40	,,	19467·5
* 23·380	4			,,	,,	19513·1
19·283	3			,,	,,	28·7
03·941	1			,,	5·4	87·3
*5087·600	5			1·39	,,	19650·2
73·344	2			,,	,,	19705·5
70·363	2			,,	,,	17·0
07·134	3			1·37	5·5	19966·0
4982·297	3			1·36	,,	20065·6
74·466	3			,,	,,	97·2
48·740	1			1·35	,,	20201·7
31·129	2			,,	5·6	73·7
28·427	1			,,	,,	84·9
26·503	1			,,	,,	92·8
22·063	3			,,	,,	20311·1
12·236	1			1·34	,,	51·7
09·185	2			,,	,,	64·4
06·275	2			,,	,,	76·5
* 00·304	6			,,	,,	20401·3
4895·436	1			,,	,,	21·6
93·620	2			,,	,,	29·2
86·832	2			,,	,,	57·5
86·464	2			,,	,,	59·1
* 83·881	6			,,	,,	69·9
81·629	1			,,	,,	79·4
79·832	2			,,	,,	86·9
79·339	1			,,	,,	88·9
63·303	1			1·33	5·7	20556·5
60·031	3			,,	,,	70·3
56·896	2			,,	,,	83·6
55·073	6			,,	,,	91·3
54·437	2			,,	,,	94·0
52·860	4			,,	,,	20606·0
45·862	4			,,	,,	35·7
40·052	5			1·32	,,	55·2
39·335	2			,,	,,	58·3
26·438	1			,,	,,	20713·5
23·497	4			,,	,,	26·1
23·310	3			,,	,,	26·9
21·813	2			,,	,,	33·4
19·857	4			,,	,,	41·8
18·396	b			,,	,,	48·1
17·589	b			,,	,,	51·6
04·986	3			1·31	,,	20806·0
04·502	2			,,	,,	08·1
4799·491	4			,,	,,	29·8
87·078	3			,,	,,	83·8
86·753	4			,,	,,	85·3
81·217	4			,,	5·8	20909·3
80·360	2			,,	,,	13·1
66·280	1			1·30	,,	74·9
63·142	1			,,	,,	88·8
61·169	5			,,	,,	97·4

* Rowland: 5123·390, 5087·610, 4900·301, 4883·867.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum, Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4752·970	4			1·30	5·8	21033·7
41·595	3			„	„	84·2
33·637	1			„	„	21119·6
32·565	3			„	„	23·9
28·710	4			1·29	„	41·6
26·031	2			„	„	53·6
04·818	1			„	5·9	21248·9
01·165	2			„	„	65·4
4699·424	2			„	„	73·4
96·976	3			„	„	84·4
92·137	2			1·28	„	21306·3
89·938	3			„	„	16·3
82·501	6			„	„	50·2
78·523	2			„	„	68·4
75·030	6			„	„	84·3
71·020	2			„	„	21402·7
67·024	2			„	„	21·0
66·567	2			„	„	23·1
59·058	3			„	„	57·6
58·497	4			„	„	60·2
53·951	2			1·27	„	81·2
52·309	2			„	„	88·8
43·863	6			„	„	21527·9
27·390	1			„	6·0	21604·4
13·165	2			1·26	„	71·1
04·977	3			„	„	21710·6
01·484	2			„	„	26·1
4596·771	4			„	„	48·4
90·972	2			„	„	76·2
85·505	1			„	„	21801·8
82·352	2			„	„	16·8
81·954	2			„	„	18·7
81·506	2			„	„	20·9
79·043	2n			1·25	„	33·6
73·746	4			„	„	57·9
70·855	2			„	„	71·7
65·120	2			„	„	99·2
64·576	2			„	6·1	21901·7
59·558	4			„	„	25·8
55·491	3			„	„	45·4
54·651	2			„	„	49·5
44·500	3			„	„	98·5
42·222	2			1·24	„	22009·5
34·298	2			„	„	48·0
27·983	4	4527·98		„	„	78·8
27·430	5	27·43		„	„	81·5
22·242	2	22·16		„	„	22106·8
14·190	3			„	„	46·2
13·764	3			„	„	48·3
06·139	6	06·12		„	„	85·7
03·534	1			1·23	„	98·6
4492·592	2			„	6·2	22252·6
91·924	3			„	„	56·0
87·683	4	87·61		„	„	77·0
87·433	3			„	„	78·2
84·621	2			„	„	92·2

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda +$	$\frac{1}{\lambda} -$	
4479·184	2			1·23	6·2	22319·3
77·628	4	4577·59		,,	,,	27·0
77·140	4	77·10		,,	,,	29·3
75·900	4	75·9		,,	,,	35·7
74·074	3			,,	,,	44·8
72·953	2			,,	,,	50·4
65·463	2	65·50		1·22	,,	87·9
46·805	4			,,	,,	22481·8
45·491	3			,,	,,	88·7
43·834	4	43·83		,,	,,	96·9
37·519	3			,,	,,	22528·9
36·321	2	36·37		,,	,,	35·0
33·145	1			,,	,,	51·1
27·191	1			1·21	6·3	81·3
22·772	6	22·80		,,	,,	22604·0
18·360	1			,,	,,	26·5
17·635	2			,,	,,	30·3
15·552	2			,,	,,	40·9
02·574	1			,,	,,	22707·7
4398·201	5	4398·21		,,	,,	30·2
97·904	2			,,	,,	31·8
94·840	3			,,	,,	47·7
94·184	2			,,	,,	51·0
93·788	1			1·20	,,	53·1
87·908	3	87·84		,,	,,	83·6
85·649	2			,,	,,	95·3
79·499	4			,,	,,	22827·4
75·794	3			,,	,,	46·7
75·113	8	75·11		,,	,,	50·2
71·621	1			,,	,,	68·5
71·144	2			,,	,,	71·0
66·204	3	66·30		,,	6·4	96·8
58·895	5	58·91		,,	,,	22935·2
57·876	4			,,	,,	40·6
53·833	1			1·19	,,	61·9
52·499	2			,,	,,	68·9
48·957	7	48·91		,,	,,	87·6
46·323	2			,,	,,	23001·6
44·812	3			,,	,,	09·6
37·476	2			,,	,,	48·5
30·945	3	30·85		,,	,,	83·3
24·765	1			,,	,,	23116·2
22·474	2	22·4		,,	,,	28·5
18·182	1			1·18	,,	51·5
18·052	1			,,	,,	52·2
16·472	2			,,	,,	60·7
15·662	3			,,	,,	65·0
14·080	2			,,	,,	73·5
09·784	6	09·81		,,	,,	96·6
07·234	2			,,	6·5	23210·2
05·499	1			,,	,,	19·6
02·431	5	02·45		,,	,,	36·2
00·526	3			,,	,,	46·5
4291·217	3			1·17	,,	96·9

* Rowland: 4358·879.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	$\frac{1}{\lambda}$ –	
4275·650	1			1·17	6·5	23381·7
74·346	2			,,	,,	88·9
72·295	2			,,	,,	23400·1
69·001	1			,,	,,	18·2
67·085	3			,,	,,	28·6
51·343	5	4251·39		,,	6·6	23515·3
50·532	1			1·16	,,	19·9
41·924	1			,,	,,	67·6
35·852	3	35·94		,,	,,	23601·4
32·709	2			,,	,,	18·9
31·461	1			,,	,,	25·9
29·351	1			,,	,,	37·7
24·396	3			,,	,,	65·4
20·779	4	20·81		,,	,,	85·7
17·960	3			,,	,,	23701·5
13·698	3			,,	,,	25·5
13·174	2			,,	,,	27·9
09·872	1			,,	,,	47·1
04·847	4	04·84		,,	,,	75·5
4199·442	3	4199·46		1·15	6·7	23806·0
77·684	5	77·65		,,	,,	23930·0
74·287	4	74·31		,,	,,	49·6
* 67·670	3	67·81		1·14	,,	87·6
57·786	2			,,	,,	24044·7
43·017	6r	43·03		,,	6·8	24130·2
28·472	6r	28·49		,,	,,	24215·2
25·079	4	25·10		1·13	,,	35·2
10·964	3			,,	,,	24320·3
06·552	2			,,	,,	44·5
* 02·548	7r	02·60		,,	,,	68·3
4095·617	1			,,	6·9	24409·4
* 83·862	5	83·89		,,	,,	79·7
81·391	3			1·12	,,	94·0
81·089	2			,,	,,	96·4
* 77·522	6r	77·54		,,	,,	24517·8
65·159	1	65·20		,,	,,	92·4
48·004	2	47·98		,,	7·0	24696·5
* 47·774	4	47·81		1·11	,,	97·9
44·407	2			,,	,,	24718·4
44·235	1			,,	,,	19·1
* 39·981	4	4040·0		,,	,,	45·6
30·011	3			,,	,,	24806·8
3987·652	3	3987·4		,,	7·1	25070·3
* 82·746	6	82·75		1·10	,,	25101·2
78·775	1	78·74		,,	,,	26·3
73·597	2			,,	,,	59·0
67·847	1			1·09	,,	95·5
55·237	3			,,	7·2	25275·7
54·431	1			,,	,,	80·9
* 51·739	3	51·76		,,	,,	98·1
50·499	5	50·51		,,	,,	25306·1
46·350	2			,,	,,	32·6
30·799	4	30·84		,,	,,	25432·9

* Rowland: 4167·737, 4102·541, 4083·783, 4077·498, 4047·823, 4040·013, 3982·742, 3951·765, 3950·497.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	$\frac{1}{\lambda}$ −	
3904·738	3	3904·72		1·08	7·3	25602·6
00·425	2			,,	,,	31·0
3892·570	2			,,	,,	82·7
90·281	1			1·07	,,	97·3
87·928	3			,,	,,	25713·3
78·418	2	3878·47		,,	,,	76·4
52·541	1			,,	,,	25949·6
46·805	1			1·06	,,	88·3
40·575	2			,,	,,	26030·5
33·006	2	33·00		,,	,,	81·9
26·064	2	26·00		,,	,,	26129·2
18·513	3	18·49		,,	,,	80·9
*3788·839	5	3788·88		,,	7·4	26384·9
* 74·494	5	74·51		1·05	,,	26486·2
70·740	1			1·04	7·5	26512·5
47·695	3	47·70		,,	,,	26675·5
38·772	2			,,	,,	26739·2
35·756	1			1·03	,,	60·8
34·422	1			,,	,,	70·4
24·920	3			,,	7·6	26838·7
18·237	3			,,	,,	86·8
* 10·448	6r	10·41		,,	,,	26941·3
3697·923	2	3697·88		,,	,,	27034·6
96·721	2			,,	,,	43·4
93·989	1			,,	,,	63·4
92·667	4			,,	,,	73·1
82·985	1	82·85		,,	7·7	27144·2
82·748	1			,,	,,	45·9
68·640	3	68·67		,,	,,	27250·3
64·744	8	64·76		,,	,,	79·3
61·086	2			,,	,,	27306·5
56·390	2	56·30		,,	,,	41·6
54·796	2	54·77		,,	,,	54·6
53·636	2			,,	,,	62·3
52·801	1			,,	,,	68·5
46·363	2	46·35 Sa		,,	,,	27416·9
45·567	3	45·54		,,	,,	22·9
39·422	3			,,	,,	69·2
35·471	2			,,	7·8	98·9
* 33·267	4	33·28		,,	,,	27515·6
* 28·852	7	28·89		,,	,,	49·1
* 21·099	5	21·12		,,	,,	27603·2
* 11·194	6	11·19		,,	,,	83·9
* 02·069	6	02·12		,,	,,	27754·0
* 00·884	7	00·90		,,	,,	63·1
*3593·071	5	3593·11		,,	7·9	27823·4
* 84·656	2	84·71		,,	,,	88·9
76·209	3			,,	,,	27954·7
71·587	2			,,	,,	90·8
52·843	4			,,	,,	28138·6
* 49·153	7	49·21		,,	8·0	68·7
13·036	3			,,	,,	28457·4
11·354	3			,,	,,	71·0
3499·044	3n			,,	8·1	28571·1

* Rowland: 3788·839, 3774·473.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
*3496·233	6	3496·25		1·03	8·1	28594·1
85·885	4			,,	,,	28679·0
84·208	2			,,	,,	92·7
68·028	3	68·05		,,	8·2	28726·5
61·168	2	61·15		,,	,,	92·0
54·322	2n	54·23		,,	,,	28940·9
51·082	3			,,	,,	68·0
48·962	5	48·98		,,	,,	88·9
33·159	1			,,	,,	29119·5
12·620	2			,,	8·3	94·7
09·914	1			,,	,,	29324·6
3397·169	3			,,	,,	29428·0
90·021	1			,,	8·4	89·9
88·725	3			,,	,,	29501·2
83·206	2			,,	,,	49·3
82·975	2			,,	,,	51·4
80·054	1			,,	,,	87·0
77·863	2			,,	,,	96·2
64·923	2			0·94	,,	29710·0
62·381	3	3362·20		,,	,,	32·5
62·131	4			,,	,,	34·7
59·082	2			,,	8·5	61·6
54·979	1			,,	,,	99·6
54·749	1			,,	,,	29800·4
44·680	1n			,,	,,	89·7
40·528	2			,,	,,	29926·9
37·986	1			,,	,,	50·8
35·349	1			0·93	,,	73·5
31·335	1			,,	,,	30009·5
31·029	2			,,	,,	12·3
* 28·013	6	28·11		,,	,,	39·5
19·922	1			,,	8·6	30112·6
18·700	1			,,	,,	23·7
08·525	1			,,	,,	30216·3
3293·599	1n			0·92	,,	30343·3
90·713	1			,,	,,	79·9
82·594	1	3282·7		,,	8·7	30454·9
80·055	3			,,	,,	78·7
78·576	2			,,	,,	92·3
52·408	3			,,	8·8	30742·6
* 42·408	7	42·49		0·91	,,	30833·5
* 16·812	6	16·87		0·90	,,	31077·9
06·652	1			,,	8·9	31176·3
* 03·450	5	03·51		,,	,,	31207·4
* 00·386	5	00·44		,,	,,	37·3
*3195·741	7	3195·80		,,	,,	82·8
91·627	1			,,	,,	31323·1
91·438	4			,,	,,	24·9
79·539	5			0·89	9·0	31442·1
73·179	4	73·40		,,	,,	31505·2
55·785	1			,,	,,	31678·8
35·285	3	35·30		,,	9·1	31885·8
30·059	3			0·88	,,	31936·8
14·415	2	14·6		,,	,,	32099·6

* Rowland: 3328·016, 3242·395, 3216·807, 3203·435, 3200·407, 3195·705.

YTTRIUM—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
3112·151	3	3112·2		0·88	9·2	32122·9
11·924	3			,,	,,	25·3
09·007	2			,,	,,	55·4
04·808	1			,,	,,	98·1
03·846	2			,,	,,	32208·9
3096·741	1			,,	,,	82·8
95·998	3	3096·04		0·87	,,	90·6
91·850	1			,,	,,	32333·9
86·981	2			,,	,,	84·9
76·634	2			,,	9·3	32493·7
72·479	2			,,	,,	32537·7
59·639	1			0·86	,,	32674·3
50·015	1			,,	9·4	32777 3
47·252	2			,,	,,	32807·0
45·489	3			,,	,,	26·0
44·956	1			,,	,,	31·8
38·599	1			,,	,,	32900·4
36·710	1			,,	,,	16·0
22·404	3			,,	9·5	33076·7
21·844	3			0·85	,,	82·9
10·255	1			,,	,,	33210·3
2997·069	3			,,	9·6	33359·4
95·383	2			,,	,,	75·1
84·376	4			,,	,,	98·4
74·710	3			,,	,,	33507·1
74·042	1			0·84	,,	33614·6
65·096	4			,,	9·7	33715·9
55·999	1			,,	,,	33819·8
48·533	4			,,	,,	33905·5
30·128	2			,,	9·8	34118·4
19·167	3			0·83	9·9	34499·1
2890·497	1			,,	,,	34586·2
86·585	2			0·82	10·0	34633·0
84·583	1			,,	,,	57·1
56·419	1			,,	10·1	34998·8
54·544	2			0·81	,,	35021·8
26·450	1			,,	10·2	35369·9
22·694	2			,,	,,	35417·0
18·982	1	2818·88		0·80	10·3	63·5
13·773	1			,,	,,	35529·2
00·319	1	00·30		,,	10·4	35709·8
2791·319	1			,,	,,	35815·0
85·293	1	2785·32		,,	,,	92·5
60·174	3			,,	10·5	36219·0
30·190	2			0·79	10·6	36616·8
23·096	3			0·78	10·7	36712·3
2672·190	1			,,	10·9	37411·6
2547·661	1			0·77	11·5	39240·2
40·384	1			0·74	,,	39352·6
2476·756	2			,,	11·8	40363·6
63·826	2			0·73	11·9	40575·4
60·656	1	2460·73		0·72	,,	40627·7
45·688	1			,,	12·0	40876·3
45·309	2			,,	,,	82·7
24·246	2			,,	12·2	41237·8
22·278	4	22·32		,,	,,	71·3

Yttrium—*continued.*

Wave-length (Kayser) Arc Spectrum	Intensity and Character	Spark Spectrum. Exner and Haschek	Lohse Arc Spark	Reduction to Vacuum $\lambda +$	$\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2417·364	1			0·72	12·2	41355·2
2385·298	2			0·71	12·4	41911·1
61·883	1			,,	12·6	42326·5
58·798	2			0·70	,,	81·9
55·465	1			,,	,,	42441·9
54·266	2			,,	,,	83·5
32·651	2			,,	12·8	42857·0
31·732	1			,,	,,	73·8
2289·087	2			,,	13·1	43672·4
83·722	2			0·69	13·2	43775·0
83·370	1			,,	,,	81·7
77·738	1			,,	,,	43890·0
74·171	2			0·68	13·3	43958·7
72·884	1			,,	,,	83·7
71·853	1			,,	,,	44003·6
67·152	1			,,	,,	94·9
65·110	2			,,	,,	44134·7
64·452	2			,,	,,	47·5
62·768	1			,,	,,	80·3
60·661	1			,,	13·4	44221·4
60·157	2			,,	,,	31·3
59·594	2			,,	,,	42·3
59·339	1			,,	,,	57·3
49·240	1			,,	13·5	44445·9
45·720	1			,,	,,	44515·6
43·097	3			,,	,,	67·8
42·643	1			,,	,,	76·8
40·695	1			,,	,,	44615·6
36·384	1			,,	13·6	44701·4
31·276	1			,,	,,	44803·7
28·241	1			,,	,,	64·8
27·849	1			0·67	,,	72·7

Line Spectrum of Sulphur.

Eder and Valenta, 'Denkschr. kais. Akad. Wissensch. Wien,' lxvii. 1898.

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
				5559·129	1
		5665·123	4	56·141	4n
		62·741	1n	36·968	3
6400		60·289	6	26·458	5n
6390		48·565	1	20·749	3
25		47·296	8	18·968	3n
10		45·920	2n	09·799	10
6290		40·535	4	5478·589	2n
		40·257	8	77·649	1
		16·844	4	75·209	2
		06·349	8	73·791	8
		5579·327	6	68·565	1
5819·543	2	65·097	8	54·000	10

LINE SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character
5434·737	2
32·994	10
28·907	9
01·035	3n
5345·832	8
20·894	8
5233·187	1
30·040	1
27·406	1
27·072	1
20·872	1
19·650	3
12·803	8
07·482	2
01·520	2
01·149	6
5160·348	2
42·512	3
03·535	4
5098·890	1
51·874	1
47·499	3
39·596	2
32·657	8
27·408	4
14·248	8
11·815	3
09·762	6
07·010	1
4993·733	3
92·152	5
42·649	2
25·493	6
24·269	5
17·410	4n
02·656	2
4885·831	3
24·353	2n
19·834	1
11·967	4
92·333	2
4716·382	4
4677·804	2
68·738	2

Wave-length	Intensity and Character
4661·782	1b^{v}
56·916	3
51·043	1
50·440	1
49·328	3
48·416	1
47·614	1n
42·024	2
39·024	1
24·322	1n
13·618	1
4596·368	1
91·285	1
91·164	2
62·118	2
52·592	5
49·723	3
25·159	6
24·817	2
04·370	3
4499·450	1
86·856	2
85·907	2
83·647	4
81·661	1
78·633	1
65·329	1
64·618	5
63·761	5b^{v}
56·584	2
40·043	4
32·561	3
31·131	1b^{v}
18·982	2
17·134	3
15·052	4
4393·862	3
92·012	2
67·037	2
64·873	4
62·610	6
61·671	5
60·625	1
54·739	5
51·408	2
49·551	3
47·558	1
45·637	1
40·444	4
33·947	1
32·852	5
30·798	1
19·762	1
18·847	3
17·299	2
4294·558	8b^{v}
91·606	1

Wave-length	Intensity and Character
4285·133	8
83·825	2
83·318	1
82·741	3
78·670	3
69·942	4
67·959	4
67·255	6r
59·408	2
57·603	3
53·772	10r
50·150	1
36·230	1
31·182	4
27·590	2
21·810	2
17·397	4
4193·667	2
89·896	5b^{v}
86·120	1
85·631	2
78·992	2
75·415	3
74·471	7b^{v}
74·179	4
68·554	4
65·255	1
65·127	3b^{v}
62·856	10
62·539	2
53·269	10b^{v}
49·068	2
47·126	3
45·266	10
44·027	1
42·390	8b^{v}
33·041	1
27·724	2
19·377	3
12·472	2 n
12·319	2 n
11·670	5
05·151	1
4099·607	3
99·360	2
95·288	2
91·372	1
76·024	4
72·252	3
70·077	3
69·802	2
64·634	3b
50·328	2
32·956	4b^{v}
28·995	6
11·469	1
09·566	1

LINE SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4007·995	2	3861·541	1	3618·937	1
06·700	1	60·833	3b	17·086	4b
04·045	1	53·280	3		
3999·026	3	51·312	3b^{v}	00·307	2n
98·998	4b^{v}	47·319	2	3596·152	3
		45·336	1	94·575	3
98·127	3	42·502	2b	67·382	2n
93·706	5	39·368	2	60·857	1n
91·144	4b^{v}	38·440	10	56·506	1n
		37·882	8	49·920	2b
86·158	5	31·980	4	43·856	3b
83·924	6	3794·841	5		
82·893	1b^{v}	83·543	2b	40·416	3
		79·030	4	3499·566	1b
81·923	1	74·713	2		
80·002	4b^{v}	60·030	2	97·438	8
		54·879	1	83·140	1
74·316	1	50·927	3	79·435	8b
73·341	4	49·554	4	74·061	6
70·820	3b	48·039	5	71·014	1n
70·640	3b	44·488	2	3390·354	3
63·279	3	27·457	3b	87·242	5
61·695	4	17·864	8b	85·986	2n
59·468	1	12·868	2b	77·300	1
59·189	2	10·604	2b	73·402	3n
54·457	2	09·470	6b	72·285	1n
50·866	1n	00·323	2b	70·490	4
47·326	2n	3699·529	3b	69·624	3
45·059	1	98·046	1	68·210	2
39·897	1n	96·373	3b	67·306	4
33·650	3b	89·639	1	63·294	1n
32·437	2	80·671	1	56·567	1n
32·104	3	78·329	4b	55·233	1
28·734	8	72·436	3	44·216	2n
23·788	3b^{v}	69·139	6b	41·612	4
		63·513	1	40·508	3
20·997	2	62·107	5	30·924	1
19·550	3	56·715	3	25·013	5b
18·312	1	55·435	1	24·160	4
12·149	3	54·669	1	17·205	2
07·285	2	53·559	1n	14·643	1
3899·501	2	38·267	2	08·953	3
94·159	1	37·131	2	05·774	2
92·759	2b	36·305	1	01·806	1
82·366	3	32·144	8	01·211	2
76·353	2b	26·508	3		
64·773	1b	22·892	2		

Band Spectrum of Sulphur.

Eder and Valenta, 'Denkschr. kais. Akad. Wissensch. Wien,' lxvii. 1898.

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
6380		5582·183	1	5556·189	2
20		81·192	1	55·654	3b
6265		80·882	1	55·209	1
6165		80·506	3	54·788	4
00		80·124	2	54·529	1
6036		79·536	1	54·197	3
5967		79·012	3	53·775	3b
00		78·871	3	53·251	2
5838		77·750	3	52·820	3
5779		77·424	3	52·514	1
12		76·891	2b	52·195	1
5653		76·356	1	51·836	3
01·812	3n	75·687	3	51·243	4
01·411	5	75·244	3	50·849	4
00·894	3	74·719	1	50·276	5
00·669	3	74·437	3	49·682	4b
5599·778	4	73·972	1		
99·477	4b	73·586	3	49·067	4
98·916	4	72·356	2	48·694	1
98·568	4	71·830	2	48·383	3
98·076	4	71·469	5	47·985	1
97·717	1	70·972	1	47·643	3
97·376	4	70·639	1	47·361	2
97·169	2	70·320	2	47·069	1
96·836	1	69·605	2	46·666	2
96·444	4b	69·112	4	46·409	2
95·898	4b	68·632	1	46·051	3
95·505	1	68·337	3	45·638	4
94·960	5b	68·030	3	45·178	4
		67·603	3	44·653	5
94·310	5b	67·235	2	44·220	4
93·864	5s	66·883	1	43·594	6
93·058	2b	66·622	2	43·177	2
92·649	1	66·369	2	42·747	5b
92·069	1	65·911	2	42·214	4
91·683	4	65·280	3	41·900	1
91·425	1	64·860	2	41·491	4
90·694	3	64·611	2	41·002	2
90·292	3b	63·976	5	40·712	5
89·798	4	63·132	1	40·235	3
88·813	2	62·717	1b	39·663	1
88·469	2	62·395	2	39·159	3
88·075	3b	61·886	3	38·621	6
87·408	1	61·441	4	38·189	3b
86·991	2	60·922	3b	37·836	3b
86·526	2b	60·407	2	37·309	5
86·168	2	59·787	3	36·926	4
85·775	3	59·155	5	36·595	4
85·229	3	58·794	3	36·303	4
84·699	2	58·251	1b	35·781	6
84·331	2			35·347	4
83·900	5b	57·809	3	34·943	3
		57·296	3	34·526	6
82·913	1	56·843	5	34·132	3s
82·603	3	56·512	1	33·744	6s

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
5533·196	5b	5505·771	2s	5478·692	6
		05·278	2b	78·228	3
		04·986	1	77·606	8
32·691	3b	04·681	1	77·023	3b
		04·295	1	76·597	3
32·169	6	03·893	6	76·270	3
31·422	8	03·449	3b	75·770	4
30·767	3	02·589	5	75·346	5
30·214	2	02·213	4	74·950	3
29·901	2	01·350	1	74·351	4b
29·621	4	00·574	4	73·858	3s
28·912	2b	00·398	2	73·374	3
28·521	2	5499·733	6	73·049	2
28·126	4	99·150	2	72·949	4
27·657	4	98·816	1	72·782	2
27·240	2	98·475	3	72·500	1
26·765	1	98·104	2	72·243	3
26·379	3b	97·395	2	71·390	3
25·869	3b	97·014	4	70·780	1
25·438	1	96·703	3	70·278	2
25·154	3	96·372	3	69·931	4
24·680	1n	95·401	5	69·469	3
24·420	2n	94·777	4	69·120	1
23·540	3	94·381	4	68·831	3
22·249	1	93·982	3	68·299	3
		93·505	1	67·886	1
21·963	4	93·312	2	67·624	2
21·232	8	92·803	8	67·053	1
20·521	2	92·105	3	66·556	1
20·150	4	91·605	1	66·183	3
19·515	1	91·418	1	65·896	3
19·145	2	91·103	1	65·658	2
18·761	2b	90·711	2	65·385	1
18·529	1	90·118	4	65·086	2
18·233	2	89·532	5	64·680	4
17·942	3	89·092	2	64·028	2
17·556	4	88·679	4	63·769	1
17·038	4	88·274	2	63·400	1
16·355	5	87·967	3	62·975	1
15·746	1	87·510	9	62·751	1
15·421	1	86·790	10	62·434	2
15·155	1	86·238	1	62·160	3
14·240	4	85·814	4	61·820	1
13·898	3	85·354	2	61·473	1
13·048	4	85·075	4b	61·160	3
12·853	1	84·525	4	60·815	2
12·432	3	83·741	1	60·560	3
11·963	1b	83·492	3	60·168	1
11·309	2b	83·248	2	59·531	1
10·460	3	82·813	4	59·191	2
10·160	1	82·395	2	58·507	4
09·594	2	81·955	3	57·779	2
09·209	3	81·398	6	57·010	3
08·806	5	80·910	2	56·783	
07·637	2b	80·607	2	55·311	
07·115	2	80·198	2	55·010	3b
06·599	4	79·916	5	54·648	3
06·256	1	79·341	6	54·098	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
5453·462	4	5424·171	3	5395·646	1
52·046	2	23·724	3	95·327	4
51·647	4	23·438	1	93·578	2
51·202	1	23·143	5	93·487	1
50·511	2	22·743	2	92·435	2
50·190	3	22·112	3	92·082	3
48·329	2	21·787	1	90·967	1
47·880	3	21·467	4		
47·459	3	21·078	4	90·716	2
47·007	3	20·793	3	90·214	1
46·355	1	20·385	2	89·552	3
45·842	1b	19·994	4	89·049	4
45·044	3	19·479	4	88·517	2
44·683	3	19·100	3	88·182	3
44·152	3	18·609	6	87·504	2
43·867	2	17·827	5	87·105	1
43·153	1b	17·359	5b	86·763	4
41·892	5b	16·580	4	86·188	5
41·504	1	16·232	4	85·861	3
41·189	4	15·149	3	85·014	1n
40·760	4	15·416	2	84·516	1
40·536	6	14·325	4	84·183	4
40·285	3b	13·909	1	83·578	3
39·155	6	13·742	1	83·100	2
38·472	3	13·402	4	82·175	3
38·246	3n	12·959	1	81·759	3
37·875	3	12·709	1	81·466	3
37·565	1	12·427	2	81·281	3
36·870	4	12·061	3	80·918	1
36·440	4b	11·737	2	80·318	3b
35·932	4	11·360	1	79·346	7
35·367	3	11·061	3	78·959	5
34·426	1	10·447	5	78·061	3
33·922	2	09·790	4	77·316	6
33·600	4	09·402	1	76·897	5
32·962	6	09·098	2	76·462	1
32·527	2	08·680	2	76·173	3
31·932	3	08·315	3	75·486	3
	8	07·998	1	75·158	2
31·219	or	07·691	5	74·695	2
	10	07·047	3	74·346	3
30·507	2	06·547	1	73·680	3
30·198	1	06·301	2	73·195	5
29·566	4	05·013	3	72·690	5
29·260	3	04·141	2	72·046	2
28·940	4	02·954	3	71·433	3
28·656	1	02·590	1	71·147	3
28·349	1	01·957	2	70·810	2
28·068	5	01·593	1	70·473	3
27·685	1	01·185	3	69·944	1
27·272	3	00·805	1b	69·673	2s
26·838	1	5399·684	2	69·384	1
26·655	2	99·350	1	68·989	4
26·197	6	98·996	3	68·441	1
25·712	2	98·285	3	68·314	2
25·390	3	96·479	2	67·978	3
24·908	5	96·226	2	67·588	3b
24·514	2	95·841	1	66·993	4

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
5366·482	5	5333·106	2	5305·501	3
65·380	4	32·817	1	05·113	5
65·355	1	32·525	2	04·404	1
65·093	1	32·153	3	03·962	3
64·697	6	31·522	1n	03·444	5n
64·237	3	30·789	2	03·274	1
63·814	5	30·295	4	01·986	1
63·297	5	29·516	2b	01·381	2
62·896	3	27·921	1	00·924	4
62·520	1	27·671	1	00·476	1
62·140	3	27·369	2	5299·973	2
61·678	2	26·731	1	99·601	1
61·531	2	26·301	5	99·071	3
61·158	3	25·715	4	98·795	3
60·892	1	25·223	2	98·154	1
60·627	3	24·873	1	97·997	2
60·279	4	23·851	2	97·312	2
59·806	5	23·587	2	96·983	2
58·845	4	23·241	2	96·015	2
58·263	3	22·867	2	95·584	2
57·740	2	22·271	1	94·551	1
57·367	3	21·858	3	94·031	3
56·973	4	21·536	3 b	93·300	3
56·203	2b	21·240	3 b	92·240	3
55·540	2b	20·651	1	90·799	1b
54·883	1b	20·203	3	90·330	3
54·019	1b	19·835	1	89·848	3
53·062	2b	19·585	2	89·006	2b
52·152	2b	19·311	3	88·259	2b
51·273	3	18·654	4	87·585	3
50·816	1	17·883	5	86·932	1
50·405	3	17·361	1	86·482	2
49·898	2	17·119	2	85·746	3
49·390	1	16·877	1	84·913	2
48·912	2	16·586	2	84·450	2
48·361	2	16·202	4	83·016	2
46·911	3	15·720	2	82·630	2
46·163	2n	15·338	2	82·289	1
		14·998	6	81·579	1
45·194	1n	14·481	2	80·228	1
44·041	2n	14·125	8	79·898	2
43·007	3	13·614	3	79·433	2
42·359	1	13·272	6	78·548	3
41·953	1	12·879	1	78·247	2
40·898	3n	12·506	3	77·876	1
40·121	3	11·760	6	77·440	1
38·777	1	10·621	5n	77·101	1n
38·257	3			76·733	1n
37·890	1	09·823	5	76·378	4
37·476	2	09·410	3	75·901	1
37·285	2	09·071	1	75·528	3
36·556	1	08·191	2	74·276	1
36·127	1	07·847	3	73·990	1
35·510	3	07·525	1	73·592	1
34·833	4	07·121	3	73·323	2
34·234	1b	06·783	1	72·999	3
33·939	1	06·231	3	72·689	2
33·592	3	05·874	2	72·335	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
5271·872	1	5244·577	3n	5212·052	2
71·316	2	43·906	1	11·593	1n
70·558	3	43·212	3		
69·378	1	42·702	2n	10·931	4s
69·089	1	42·282	1	10·617	2
68·833	2	42·027	1	10·017	2n
68·508	2	41·737	2	09·045	2n
67·847	2	40·856	2	08·782	4n
67·401	1	40·069	2	08·306	3b
67·254	1	39·682	2	07·417	3
67·024	1	39·320	2	06·906	5b
66·540	1	38·477	2n	06·409	1
66·155	3	38·114	1	05·737	1
65·512	3n	37·089	2	05·227	6b
		36·527	1	04·779	1
65·109	1	36·079	2	04·296	2
64·917	2	35·472	3	03·710	4
64·044	1	34·131	2	03·341	1
63·500	4n	32·817	1n	02·904	2
63·017	3n			02·465	3
62·484	1n	32·182	1	01·872	2
61·990	1	31·328	2	01·652	3b
61·451	5n	30·792	1	01·156	2
61·247	1	30·329	1	00·756	2
60·608	2	29·835	2	00·333	2
60·269	1n	29·109	1n	5199·956	3
59·841	4	28·457	2	99·582	1
59·552	2	27·943	1	99·309	2
59·192	1	26·798	1	99·000	3
58·607	2	26·155	2	98·475	2
58·340	3	25·734	1	97·817	4b
57·986	1n	25·258	1	97·675	2
57·405	2	24·676	2n	96·769	3
56·803	4	24·454	1n	96·588	2
56·043	2n	23·947	2	95·966	2
55·739	3	23·671	1	95·728	2
55·269	2	23·307	1	94·782	2
54·974	1	22·983	1	94·048	5b
54·534	1	22·245	2	93·436	3b
54·153	4	21·546	2n	92·734	1s
53·756	3	21·274	1n	92·288	2
53·303	2	20·690	3	91·956	2
52·981	2	20·229	2	90·521	1
52·700	3	19·882	1	90·117	3
52·158	3n	19·544	1	88·573	1b
51·677	3	19·201	2	88·100	1
51·359	3	18·668	1	87·335	1
51·118	3	18·037	1	86·880	1
50·512	2n	17·704	4	86·612	1
49·820	3	17·019	3	86·033	1
49·315	2	15·935	1	85·016	1
48·958	2	15·409	3	84·426	3
48·090	3	14·796	3b	83·775	2n
47·126	2	14·451	1	83·063	1
46·801	2	13·835	1b	82·670	1
46·336	3n	13·158	3	82·165	1
45·587	3	12·875	1	81·562	2n
45·015	2	12·594	2	81·169	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
5180·855	2n	5146·732	3b		
78·761	2	46·257	2	5102·903	3
78·043	3b	45·783	4b	02·608	3
76·861	1	45·031	2	02·140	2
76·401	2n	44·482	3	01·965	2
76·361	1n	44·000	2	00·853	2
75·881	1n	43·458	2	00·494	4
75·229	2n	43·131	1	5099·627	2
73·653	2n	42·574	1n	98·972	4
73·171	2n			98·392	2
72·692	1	41·671	2	97·634	4
72·307	1	40·923	1n	96·911	1b
71·175	2	40·448	2n	96·457	1
70·660	1	39·074	1	95·983	2
70·353	2	38·400	2	95·055	2
69·665	1	37·643	1n	94·684	3
68·592	2	37·001	1	94·225	2
68·122	2	36·624	1	93·912	2
66·239	1n	36·113	1	93·098	2
		35·663	2n	92·697	3n
66·142	2n	35·398	2n	92·195	1
65·330	2n	33·270	1	91·949	1n
63·880	3	32·852	1	91·541	2n
63·389	3	29·743	1	90·979	3
63·008	2	28·816	2	90·162	2
61·691	4b	28·220	1	89·388	2n
61·214	2	27·561	1	89·196	1n
60·816	2	26·914	1n	88·322	1n
59·844	5	25·783	1n	87·529	3
59·557	1			86·884	2n
59·148	1n	23·942	1n	86·270	1n
58·916	1n	23·188	1n	84·475	3
58·194	2n	22·682	1n	84·024	2
57·921	2n	21·987	2n	82·964	1n
57·509	1	20·490	1		
57·134	3	19·500	2	82·415	3
56·689	2	18·144	2	81·412	3
56·275	1	17·233	3	80·781	2
55·826	2	15·673	2	80·325	2
55·332	4	14·984	2b	79·334	1b
54·873	2b	13·655	1n	78·503	2
54·379	3	12·976	1n	78·022	1
53·960	3	12·558	1n	77·699	1
53·559	1	12·262	1n	75·217	1
53·102	2	11·631	1	74·912	2
52·655	3b	11·279	2	74·576	3
52·281	2	10·943	1	74·086	2
51·929	3	10·152	1	73·586	1b
51·615	1	09·767	1	72·729	1n
51·344	1	09·186	2	71·923	2
50·987	4	08·392	1n	71·629	1
50·583	2	07·832	2n	71·349	1
50·287	1	07·195	3	70·893	1
49·935	2	06·224	2n	70·563	2
49·583	3	05·412	2	70·181	1n
48·917	3b	04·594	2	69·757	2
48·163	4	04·239	3	69·355	1n
47·535	4	03·731	1b		

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
		5039·277	2	4999·574	2
5068·966	1	38·818	3n	99·206	3
68·568	3			98·868	2
68·099	2	38·368	1	98·556	1
67·529	2	37·866	3	97·989	5b
66·886	2n	37·004	4		
66·643	2	36·532	2	97·306	2b
65·833	3	35·866	2b	96·658	3b
65·323	2	35·366	2	96·177	3
64·973	1	35·030	1n	95·634	3
64·546	2	34·631	4n	95·141	3
64·219	1	33·881	2	94·718	4
63·825	2	33·261	2n	94·197	4
63·247	1	32·737	1b	93·775	1
62·779	1			93·208	4
62·315	2b	31·510	1b	92·712	2
61·770	2	30·301	2b	92·336	1
61·189	3	28·121	1	91·909	3
60·756	1b	27·485	1	91·642	2
		26·447	1	91·491	2
59·871	4	25·645	1	91·059	2
59·103	3	25·008	1	90·628	2n
58·636	1	24·700	2	90·258	3
58·134	3	24·377	1	89·995	3
57·626	1	22·684	1	89·543	1
56·981	4	22·043	3b	89·182	2
56·493	1	21·495	1	88·494	2
56·071	1	21·003	1	87·317	2n
55·711	3	20·525	2	87·371	1
55·444	2	19·483	2b	85·737	1
55·086	2	18·593	1b	85·304	1n
54·862	1	17·820	1	84·526	1
54·463	1b	17·096	1n	83·842	1
53·057	1	16·772	2n	83·385	1
53·290	8	15·790	1b	82·675	2
52·545	3	15·215	2b	82·162	1n
52·119	1	14·173	3n	80·833	1
51·440	5	13·449	1n	80·387	4s
51·044	5	12·821	2	79·706	1n
50·370	2	11·703	4	78·830	1n
49·590	3	11·099	3	78·083	1n
	1	10·436	2	77·286	2
48·953	2	09·677	2	76·617	1
48·544	1	09·322	1	75·282	1
48·137	2	08·988	2s	74·566	2
47·790	4	08·224	2n	73·674	1
46·730	2	07·057	3b	72·641	1
46·266	4s			71·915	1n
45·418	2	05·971	2b	70·935	1n
44·712	5	05·304	3	70·103	1
43·930	3b	03·968	2	69·433	1
43·297	4	03·713	2	68·786	1
42·770	2n	03·178	2	68·638	2
42·438	1	02·765	1n	67·576	1
41·976	3	02·020	4	67·046	1
41·438	3	01·375	3	66·176	1
40·887	4	00·578	3	65·747	1
39·694	3	00·013	2	65·549	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4964·764	3	4925·558	1n	4892·772	3b
63·511	2b	25·008	1n		
62·962	1	24·355	1n	90·525	3
62·341	2	23·598	1	89·858	1n
61·002	1	23·244	1b	89·406	1n
60·404	2	23·036	2b	88·933	1n
59·968	1	22·422	1	88·663	1n
58·993	1	22·038	1	87·852	2n
58·458	1			87·429	2n
58·264	2			85·144	2n
56·692	1	17·827	2b	84·577	1n
56·193	2	17·213	1b	84·205	2n
55·625	2b	16·603	1	83·751	1n
		16·260	1	82·399	1n
54·670	1	15·980	1	81·910	1n
54·056	1n	15·304	1n	81·214	3n
53·728	2	14·505	4	80·245	2n
53·300	1	13·684	3	79·754	1n
53·156	2b	13·214	1n	78·913	2n
52·248	1	12·617	1n		
51·889	2b	12·133	3		
51·020	2	11·260	2		
50·455	2b	10·984	2		
49·362	2	09·882	2n	75·980	2n
48·850	3	09·715	2	75·541	3n
48·458	1	09·299	1	74·927	1
47·790	3	08·818	3	74·455	1n
47·408	3	08·446	1	73·897	1n
46·968	1	07·653	3	73·164	1n
46·464	1	06·995	1	72·732	1n
46·006	1	06·210	2n	72·237	1b
45·609	1			71·931	1
45·195	1	05·557	2	71·172	3b
44·803	2	05·088	1n	70·583	2b
44·179	1	04·793	1n	70·141	1b
43·903	1	04·337	3n	69·559	1b
43·555	3	04·020	3	68·609	2b
43·169	2	03·452	3	68·447	4b
42·909	1	03·045	2	67·300	2
42·439	2b	02·606	1n	65·827	4
41·989	2	02·198	1	64·823	2b
41·552	1	01·610	4	64·286	1b
41·174	1	01·108	2	63·839	2b
40·737	1n	00·249	1b	63·366	4
40·403	3			62·881	2b
39·871	3	4899·780	3		
39·317	1	99·456	1	62·390	2
39·010	2	99·077	2	62·034	1
38·531	1	98·394	4	61·169	4
38·245	2	97·921	2	60·656	3
37·471	2	96·968	3b	60·178	3
36·995	3			59·465	1
36·588	1	96·315	3	58·956	3
35·966	1n	95·654	3	58·476	4
35·219	1	95·290	1	58·107	1
34·592	3	94·593	3b	57·626	1
27·070	1b			56·827	5
26·222	2b	93·603	1n	56·490	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4855·803	2b	4770·730	1	4749·189	3
55·273	3	70·540	1n	48·601	1n
54·898	1	70·009	1	48·416	2
54·539	1	69·508	2	48·101	3n
54·190	2n	69·259	2	47·786	1
53·726	2n	68·566	2	47·533	2
53·255	2b	68·273	1	46·847	1
52·805	2	67·939	1	46·263	1
		67·635	1	46·085	2
52·281	2	67·342	2	45·611	1b
51·702	1	66·542	2	45·252	2
51·342	3s	66·220	2	44·392	2
51·029	3s	65·504	1	43·967	1
50·180	2	65·221	2	43·741	1
49·707	3	64·762	1	43·465	1b
49·249	3	64·557	1n	42·973	3
48·701	1	64·195	3	42·572	1b
48·230	3b	63·756	2	42·153	2
47·519	2	63·476	1	41·552	1
47·088	2	63·256	1	41·148	1
46·762	2	63·042	2	41·083	2
46·124	3	62·749	1	40·680	1b
45·709	2	62·265	2	40·396	1b
45·346	1b	62·098	1	39·985	1
44·599	2	61·397	4	39·821	2
44·298	1b	60·916	1n	39·673	2
43·612	1	60·437	3b	39·384	1
42·364	2b			38·992	2
41·697	1b			38·030	2
40·666	2b	59·854	2	37·471	2n
40·187	1b	59·547	1	37·188	1
39·562	2	59·343	1	36·918	1n
4784·744	1	59·020	1	36·659	2
84·243	1	58·466	2	35·814	2
83·665	1	57·886	2	35·568	1b
83·039	1	57·818	2	35·051	2b
82·779	1			34·327	1
81·948	1	57·054	2b	33·926	4b
81·738	1			33·314	1
80·787	1n	56·367	2	33·117	1
80·396	1	56·064	1	32·982	1
80·170	1	55·757	4n	32·902	1
79·179	1	54·985	2n	32·544	1
78·738	1	54·784	2n	32·416	1
78·029	2	54·489	2n	31·947	2
77·641	2	53·379	2	31·649	4b
77·128	1n	53·150	2	31·117	1
76·656	1	52·680	2n	30·893	1
75·656	1	52·021	2	30·662	1
75·468	1	51·740	2	30·182	1
75·154	2	51·615	2	29·822	2n
74·794	1	51·144	1n	29·604	1
74·164	2	50·868	2	29·424	1
73·377	2	50·626	1	29·244	2n
72·910	3n	50·239	2	28·825	1
71·729	1	50·029	2	28·563	2
71·285	2	49·722	1	27·856	1
70·912	1	49·471	2	27·733	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4727·520	1	4709·236	3b	4690·619	3
27·067	2			90·350	1n
26·691	2	08·972	1		
26·208	3b	08·813	3	89·793	1
		08·162	1	89·602	3
25·570	2	07·935	2b	89·278	2
25·165	1	07·514	4	88·687	4b
24·717	3n	07·088	1		
24·341	2	06·808	3	88·110	3
23·901	2n	06·439	4b	87·920	3
23·756	1			87·675	1
23·378	2s	06·046	1	87·423	1
22·893	2b	05·702	4	87·220	2
22·559	3	05·356	2b	87·081	2
22·221	4			86·814	2
21·971	1	05·142	1	86·574	3
21·695	1	04·814	3	86·209	1
21·482	2	04·173	2b	85·834	2
21·194	2			85·453	4
20·607	3b	03·658	2	85·243	2
20·172	1	03·223	4	85·053	2
19·783	2	02·896	1	84·755	3
19·199	2	02·585	1	84·503	2
18·644	3	02·407	1	84·384	2
18·178	4	02·114	2	83·969	4
17·798	1	01·775	4	83·760	4
17·505	2	01·360	4	83·159	1
17·185	1	00·835	1	82·877	2
16·737	1	00·579	1	82·617	2b
16·540	1	00·397	1n	82·378	2
16·283	3	00·244	2	82·058	3
16·084	1	00·036	3	81·671	1
15·799	3	4699·628	2	81·537	3s
		99·303	1	81·240	3b
15·318	2	99·010	1	80·406	3
14·813	2	98·489	3	80·183	1
14·579	3	98·250	1	80·076	3
14·392	2	97·871	2b	79·761	3b
14·235	1	97·421	3b	79·418	4
14·098	3	97·079	1	79·135	4
13·860	2	96·911	2		
13·556	2	96·773	2	78·509	2
13·365	1	95·705	1	77·957	4
13·109	2b	95·387	1	77·762	2
12·826	4b	95·100	2	77·581	1
12·477	1	94·596	2b	77·407	1b
12·356	1	94·331	3b	77·047	3
12·034	2	94·063	1	76·810	4
11·624	1n	93·828	2b	76·348	1
11·391	2			76·157	2
11·137	3	93·100	2	75·816	4
10·941	2	92·756	1		
10·578	2b	92·526	2	75·485	3
		92·174	1	75·044	6
10·270	1	91·727	2	74·731	3
10·030	3	91·360	4	74·655	2
09·796	1	91·147	1	74·432	1
09·579	1				

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4673·953	1	4661·876	1	4645·448	1b
73·784	5b	61·799	4	45·110	1
73·402	1	61·593	1	44·734	2
73·296	4	61·446	1	44·509	1
73·065	2n	61·179	1	43·994	4
72·883	3n	60·863	8	43·568	3
72·824	3	60·443	4	43·247	3
72·424	3	60·265	1	42·297	3
72·176	3	60·044	1	41·927	1
71·940	3	59·647	8	41·736	1
71·572	3	59·493	6	41·506	4
71·383	1	59·270	4	41·255	2b
71·268	2	58·793	2	40·831	6
70·990	2	58·505	4b	40·460	4b
70·675	6			39·805	3
70·435	2			39·373	3b
70·329	6			39·196	2
		57·975	3	38·540	3
		57·496	3	38·331	2b
		57·188	8		
70·122	6	56·495	3b	37·946	1
69·883	6			37·723	2
69·474	1	56·140	6	37·363	1
69·475	5	55·691	2	36·802	3
69·042	3	55·348	3	36·621	2
68·801	4	54·131	3	36·375	2
68·483	4	54·863	4	35·943	2
68·338	3b	54·596	4	35·564	1
68·040	3b	54·233	5	35·269	2b
67·892	4	53·948	1	34·865	1
67·681	1	53·841	1	34·762	1
67·554	1	53·631	2b	34·527	4
67·369	3			34·328	4
67·147	1b	53·112	1	33·715	5
66·932	3b	52·971	3	33·155	1
66·787	1b	52·565	4	32·991	1
66·646	3	52·323	8	32·711	3
66·333	6	52·128	2	32·460	3
65·970	2	51·848	3	32·279	1
		51·331	2	32·139	4
		51·088	4	31·584	3b
65·712	2	50·814	3	31·193	2
65·357	6	50·623	3	30·924	1
64·988	4b	50·493	1	30·753	2
64·721	4b	49·993	2	30·514	1
64·381	4b	49·404	6	30·409	3
64·184	1	48·817	1	30·214	2
64·036	3	48·629	1	30·053	2
63·803	2b	48·399	3	29·652	1
		48·082	1	29·342	3
		47·980	1	28·887	1
63·622	4	47·660	2	28·659	1
63·435	1	47·385	1	28·483	2
63·163	5	47·047	1n	28·202	3
62·796	2s	46·892	1n	28·014	2
62·431	2b	46·709	4	27·486	1
62·220	4	46·404	4	27·366	1
62·099	1	45·761	4	27·101	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4626·917	1	4612·585	1	4593·533	2
26·704	2	12·327	4	92·784	3
26·465	2b	11·950	3	92·190	2b
		11·672	3	91·815	2n
		11·184	3	91·591	1
26·079	3	10·810	5	91·420	2
25·639	1	10·470	6	90·985	1n
25·419	3	10·159	2	90·712	2
25·239	2	09·546	4	90·533	1
24·983	3	09·158	3	90·509	2
24·571	2	08·786	2	90·062	1
24·321	2	08·633	2	89·818	2
24·194	3	08·284	2	89·458	2
23·834	3	07·900	3	89·164	2
23·613	2	07·447	2	88·936	1
23·399	2	07·146	3	88·551	1
23·084	1	06·744	1	88·423	2
22·853	2	06·493	2b	88·051	2
22·578	2			87·921	1
22·379	3	06·104	3	87·616	2
21·876	3	05·676	2	87·218	3
21·703	1	05·492	1	86·855	1n
21·285	1	05·288	1	86·594	1n
21·124	1	05·056	4	86·415	1
20·901	4	04·528	3	85·987	2
20·682	3	04·209	3	85·760	1
20·542	2	03·989	1	85·634	1
20·418	3	03·747	1	85·407	3
19·770	2	03·488	4	85·175	1
19·541	2	03·127	3	84·908	1
19·368	3	02·913	2	84·666	1
19·211	3	02·509	6	84·477	4
18·997	2	01·789	1	84·288	2
18·850	1	01·546	2b	84·016	1
18·705	2	01·259	1	83·834	2b
18·384	1	00·835	3s	83·626	1
18·233	2	00·386	3n	83·514	1
17·953	4	4599·825	2n	83·331	2b
17·720	1	99·407	1n	83·086	1b
17·482	1	98·488	1	82·673	2
17·161	4	98·347	2	82·321	1n
16·908	4	98·091	2b	82·111	3
16·761	5	97·757	1	81·835	2
16·208	1	97·408	4b	81·674	1
16·081	1	96·751	1b	81·317	1n
15·784	4	96·497	1	81·058	1
15·466	3	96·297	1	80·890	2
15·188	2	95·964	2	80·497	2
14·786	4	95·577	2	80·022	1
14·574	3b	95·435	1	79·625	1n
14·212	3	95·252	2	79·384	2
13·925	2	95·010	2	79·087	1
13·737	2	94·730	1	78·808	2
13·566	1	94·587	1	78·528	1
13·478	1	94·391	2	78·363	1
13·350	3	94·257	1	78·068	1
13·204	2	94·012	1	77·884	1
12·968	2	93·635	2	77·548	4

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4577·192	4	4561·012	1	4546·926	3
76·987	1	60·841	3	46·745	1
76·682	1	60·483	3	46·582	3
76·388	1	60·194	3	46·336	3
76·210	3	59·882	1	46·196	1
75·953	1	59·743	1	46·067	2
75·625	2	59·601	2	45·624	2s
75·503	1	59·311	2	45·185	3b
75·122	2	58·952	1		
74·939	2	58·770	2	44·978	1
74·698	2	58·581	2	44·771	3
74·133	4	58·267	1	44·540	6
73·890	1	57·946	3	44·275	2
73·602	4	57·495	4	44·062	4
73·208	2b	57·223	3	43·866	2
72·966	2b	56·871	3	43·736	1
72·704	3	56·437	1	43·570	2
72·273	3	56·151	3	43·284	2
71·998	1	55·928	1	42·822	4
71·872	1	55·817	2	42·617	2
71·479	1	55·701	1	42·386	6
71·312	1	55·481	1	41·948	4
71·152	2	55·252	6	41·229	3
70·982	1	54·794	5b	40·948	10b
70·765	2			40·777	10b
70·292	4	54·346	1	40·655	10b
70·037	1	54·237	1	40·395	2
69·526	3	53·859	1	40·244	2
69·277	2	53·756	1	39·997	4
68·990	1	53·616	2	39·726	4
68·581	2	53·284	2	39·470	4
68·187	3	53·112	2	39·194	2
67·674	1	52·962	1	38·982	3
67·435	2	52·272	1	38·681	4
67·325	2	52·553	3	38·438	2
67·124	2	52·392	1	38·192	1
66·830	2n	52·211	3	38·003	2
66·597	1n	51·966	1	37·778	5
66·404	3	51·741	3	37·490	5
65·880	1	51·403	3	37·181	4
65·713	2	51·027	1	36·958	4
65·635	2	50·764	4	36·774	1
65·335	1	50·445	4	36·647	1
65·198	1	49·993	1	36·572	2
65·062	1	49·628	3	36·361	4
64·798	3b	49·581	1	36·005	8
64·437	1	49 346	1	35·678	1
64·230	3	49·091	4b	35·398	8
63·864	1			35·027	10
63·552	3	48·716	1		
63·412	3	48·524	4	34·675	1
63·104	1	48·336	3	34·487	2
62·955	3	48·182	2	34·292	1
62·668	1	47·765	2b	34·135	3
62·498	2			33·883	3
61·990	1	47·442	4	33·569	5
61·651	2	47·235	1	33·254	4
61·360	3	47·109	1	33·054	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4532·762	8	4517·837	2	4502·509	1
32·583	1	17·635	1	02·325	2
32·327	4	17·407	2	02·106	3
31·895	1	17·096	3	01·943	2
31·661	3	16·947	3	01·762	2
31·476	1	16·433	2	01·333	4
31·253	4	16·177	3	01·191	8
30·992	6b	15·816	6	00·922	8
30·547	6b	15·565	4	00·578	4
30·190	4	15·320	3	00·439	2
29·995	3	15·127	1	00·128	4
29·785	3	14·888	1	4499·766	2
29·564	3	14·667	4	99·579	2
29·347	3	14·472	3	99·400	1
29·252	3	14·244	3	99·274	5
28·967	1	13·707	4	99·052	1
28·655	3	13·399	5	98·873	2
28·340	5b	13·118	3	98·645	3
27·949	1b	12·836	1	98·480	2
27·809	4b	12·650	4	98·149	8
27·580	1n	12·349	1	97·888	3
27·494	1n	12·209	1	97·672	2
27·097	4	12·102	1	97·524	2
26·740	2	11·936	3	97·330	4
26·478	3	11·734	1	97·203	4
26·298	1	11·537	1	96·995	1
25·905	4	11·345	2	96·828	6
25·651	2n	11·054	6	96·566	1
25·535	2n	10·791	5	96·462	3
25·277	1	10·534	1	96·373	3
25·077	2	10·212	1	96·178	8
24·763	4	10·015	6	95·944	4
24·408	1	09·516	6	95·646	4
24·198	5	08·999	8b	95·494	4
23·782	8			95·242	4
23·660	4	08·491	4	95·237	5
23·348	2	08·013	2	94·993	1
23·208	1	07·871	2	94·596	6b
23·083	2	07·749	1	94·508	6
22·861	3	07·456	4	94·023	3
22·581	2	07·188	4	93·807	4
22·400	2	07·057	4	93·637	4
22·027	2	06·854	1	93·281	2
21·667	4	06·489	4	93·045	5
21·338	2	06·227	6	92·805	3
20·999	1	05·821	3	92·679	4
20·797	2	05·572	3	92·310	2
20·614	3	05·368	1	92·187	2
20·081	3	05·172	2	92·096	2
19·750	4	04·946	8	91·835	3
19·511	2	04·416	2	91·472	4
19·211	2	04·229	2	91·289	1
19·074	1	03·964	5	91·110	4
18·665	3	03·713	3	90·806	5
18·492	1	03·558	3n	90·579	4
18·370	1	03·295	4s	90·375	1n
18·181	1	02·917	6	90·180	5
18·067	2	02·730	2	89·911	4

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4489·717	1	4476·098	2b	4462·573	2
89·320	10	75·867	2b	62·421	1
89·085	8	75·558	1	62·329	1
88·836	2	75·373	1	61·660	3
88·680	1	75·223	5	61·406	2
88·604	1s	74·910	1	61·015	4
88·574	1s	74·757	1	60·415	4
88·215	6	74·598	2	60·206	2
87·908	6	74·281	1	60·030	3
87·596	8	74·178	1	59·826	1
87·124	3	73·899	2b	59·628	1
86·876	6			59·519	1
86·743	3	73·614	4	59·200	2
86·495	5	73·352	4	58·855	3
86·206	5	73·107	1	58·503	4
85·877	2	72·948	1	58·293	4
85·803	2	72·574	4	57·814	3n
85·591	6	72·204	4	57·634	3n
85·401	6	72·139	2	57·429	2
85·067	5	71·964	6	57·300	2
84·851	5	71·714	1	57·083	1
84·616	5	71·537	2	56·903	2n
84·375	5	71·288	1	56·708	2n
83·891	3b	71·198	1	56·523	2n
		70·985	1	56·407	2n
83·657	4	70·667	5	56·226	1n
83·476	2	70·439	1	56·118	1n
83·289	3	70·363	1	55·916	1
83·109	3	70·171	3	55·738	2
82·835	5	70·063	1	55·538	3
82·637	2	69·849	2	55·386	3
82·400	4	69·497	2b	55·211	2
82·219	4	68·997	3	55·115	2
81·983	5	68·565	2	54·802	1
81·787	5	68·304	2	54·684	1
81·632	5	68·219	2	54·504	3
81·412	2	67·964	3	54·343	1
81·136	8b	67·735	3	54·176	1
80·912	1	67·566	1	54·048	2
80·779	1	67·259	2	53·875	1
80·501	8	67·088	3	53·479	5
80·262	2	66·883	1	53·306	5
80·092	2b	66·727	1	53·098	1
79·782	3	66·488	2	52·667	4
79·523	2	66·201	2	52·303	1
79·346	2	66·060	2	52·090	1
79·265	4	65·820	2	51·973	1
79·047	1	65·392	3	51·751	1n
78·893	1	65·232	2	51·562	1
78·647	3	64·798	3	51·371	3
78·390	2	64·503	3	51·073	2n
78·187	1	64·294	1	50·881	3n
78·023	1	64·210	1	50·608	3n
78·020	8	63·850	4	50·296	2n
77·448	3	63·447	2n	50·0 9	4
77·091	3	63·166	2	49·608	4
76·924	3	63·002	1	49·247	4
76·403	5	62·868	1	48·993	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4448·751	1	4433·123	1	4414·842	2
48·443	1	32·865	1	14·603	1
48·112	5	32·643	2	14·281	2
47·886	3	32·085	1	14·100	3
47·171	2	31·923	1	13·774	2
47·017	2	31·643	2	13·574	1
46·787	1	31·349	1	13·421	1
46·611	2	30·898	1b	13·139	2
46·437	2	30·401	2b	12·896	1
46·313	2	29·955	1b	12·548	2
46·094	1	29·726	1b	12·373	2
45·916	1	29·131	1b	12·001	2
45·567	2	28·792	3	11·682	2
45·476	2	28·421	1	11·448	1
45·161	2	28·030	1	11·178	1b
44·947	2	27·714	1	10·920	1
44·798	2	27·569	1	10·745	1
44·365	1	27·179	1	10·630	1
44·208	2	26·932	2	10·293	2
43·780	1	26·559	1b	09·907	2
43·474	2			09·705	1
43·389	2	25·884	2b	09·494	2
43·287	2	25·044	1	09·319	2
42·914	3	24·797	1	09·107	1
42·591	4	24·487	3b	08·602	3
42·078	1	24·200	1	08·178	2
41·890	1	23·999	1	07·892	2
41·750	2	23·749	1	07·798	1
41·595	3	23·659	2	07·400	1
41·419	2	23·249	1	07·171	1
41·045	1	23·014	1	07·019	1
40·883	2	22·861	1	06·874	1
40·701	2	22·554	1	06·754	2
40·442	3	22·201	3	06·517	3
40·140	1	21·731	1	06·317	1
39·669	3	21·395	1	06·117	2
39·441	4	21·201	1	05·698	2b
38·678	3	20·904	1b	05·415	1
38·542	3	20·617	2	05·156	2
37·708	2	20·290	2	04·161	4
37·653	3s	19·856	3b	03·867	1
37·148	1	19·687	1	03·633	4
36·906	3	19·401	1	03·318	1
36·801	3	19·079	1	03·012	2
36·450		18·862	2	02·750	1
36·196	4	18·430	3b	02·594	1
35·937	2			02·133	4
35·686	2			01·499	4
35·598	2	17·836	1	01·433	1
35·215	3	17·498	3	01·015	2
35·132	3	17·040	1	00·944	2
34·742	1	16·691	2	00·730	2
34·596	2	16·411	2	00·536	3
34·429	1	15·948	1	00·289	2
34·173	1	15·488	1	4399·961	2
33·907	4	15·319	1	99·760	1
33·583	1	15·140	1	99·580	2
33·2 0	1	14·979	2	99·460	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4399·172	1	4382·873	4	4369·613	2
98·889	2	82·699	3	69·299	3
98·712	2	82·495	3	69·113	3
98·425	5	82·306	1	68·685	6
97·836	1	82·179	2	68·418	5
97·623	6	81·877	4	68·266	5
97·141	1	81·623	3	67·951	3
96·889	4	81·538	2	67·746	4b
96·549	2	81·396	2	67·466	8
96·180	4	81·259	1	67·146	1
95·605	4	81·131	2	66·968	10
95·250	1	80·731	6	66·678	3
94·886	6	80·373	6	66·468	1
94·321	6	79·971	3	66·202	10
94·101	5	79·715	3b	65·829	8
93·751	1			65·507	5
93·742	3	79·531	1	65·129	4
93·631	3	79·259	8	64·911	4
93·421	1	79·020	4	64·745	4
93·172	2	78·610	6	64·481	8
92·936	1	78·321	1	64·208	8
92·768	4	78·114	4	63·919	8
92·471	6	77·894	4	63·730	4
92·134	1	77·609	4	63·482	4
91·941	4	77·499	4	63·262	5
91·655	1	77·188	8b	62·946	8
91·479	4			62·757	4
91·306	2	76·867	4	62·488	8
91·005	3	76·710	4	62·037	10
90·751	2	76·423	3b	61·668	8
90·331	5			61·357	6
90·099	2	75·964	4	61·053	5
89·919	1	75·739	4	60·809	6
89·574	4	75·542	4	60·394	5
89·155	3	75·323	3	60·196	1
88·858	3	75·039	4	60·032	2
88·495	4	74·832	4	59·867	3
88·144	5	74·568	3	59·641	6
87·842	2	74·394	1	59·500	1
87·636	4	74·310	1	59·358	2
87·350	1	74·108	4	59·115	8
87·208	2	73·918	2	58·859	3
86·917	4	73·744	2b	58·743	1
86·745	3	73·622	5	58·586	4
86·457	4	73·477	6b	58·402	3
85·849	3	73·065	8	58·029	4
85·615	5	72·531	3	57·829	6
85·441	1	72·289	3	57·618	1
85·010	5	72·059	4	57·414	1
84·945	4b	71·754	5	57·232	1
		71·461	5	56·909	6
84·661	1	71·254	1	56·695	4
84·355	4	71·004	4	56·469	3
84·125	1	70·696	5	56·167	6
83·949	3	70·396	2	55·875	6
83·520	3	70·326	2	55·677	5
83·330	2	70·059	5	55·508	6
83·155	1	69·859	2	55·207	6

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4354·973	1	4342·966	2	4329·820	8
54·783	2	42·815	2	29·415	5
54·628	2	42·733	2	29·162	5
54·474	1	42·391	3	28·799	5
54·293	3	42·144	2	28·675	5
54·182	3	41·925	2	28·439	4
54·074	3	41·818	6	28·230	1
53·896	1	41·572	1	28·118	2
53·782	1	41·372	6	27·945	4
53·560	1	41·056	1	27·646	6
53·387	2	40·855	6	27·445	6
53·264	1	40·587	3	27·149	8
53·052	4	40·439	4	26·794	1
52·827	4	40·088	6	26·606	2
52·527	4		1	26·420	3
52·339	1	39·839	6	26·172	5
52·197	1	39·421	4	25·786	1
52·002	2	39·319	4	25·633	1
51·838	1	39·100	5	25·447	3
51·709	5	38·907	1	25·213	1
51·212	1	38·746	3	25·058	2
50·984	4	38·532	2b	24·938	4
50·745	1	38·097	6	24·787	4
50·667	1	37·754	2	24·595	1
50·475	2	37·572	1	24·456	2
50·282	1	37·317	2	24·312	3
50·177	3	37·257	2	24·132	1
50·073	3	37·050	1	23·782	5
49·811	2	36·854	2	23·212	3
49·665	1	36·645	8	22·989	3
49·522	1	36·350	6	22·788	2
49·384	1	36·174	6	22·590	3
49·207	5	35·824	5	22·425	3
48·883	3	35·687	5	22·216	3
48·489	8	35·371	4	22·102	2
48·120	1	35·178	4	21·942	1
47·957	4	34·839	1	21·817	1n
47·792	4	34·763	6	21·726	2
47·667	4	34·454	5	21·624	3
47·447	4	34·185	4	21·422	5
47·246	3	34·117	4	21·217	1
47·040	2	33·803	6	21·158	1
46·871	1	33·632	6	20·925	3
46·712	5	33·441	1	20·795	5
46·445	3	33·299	1	20·692	3
46·061	8	32·801	8	20·328	2
45·680	2	32·783	1	20·164	4
45·534	5	32·618	1	19·884	5
45·232	3	32·381	6	19·614	4
45·019	4	32·145	1	19·416	1
44·763	3	31·962	8	19·225	3
44·560	3	31·623	5	19·085	3
44·339	4	31·310	5	18·907	5
44·106	6	31·108	2	18·636	2
43·886	1	30·990	6	18·485	2
43·674	8	30·687	3	18·310	5
43·488	8	30·541	1	18·009	5
43·165	4	30·252	10b	17·790	5

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4317·258	4	4303·860	3	4290·281	1
17·155	3	03·688	1n	90·145	1
17·062	3	03·246	3	89·979	2
16·969	1	03·137	3	89·763	4
16·753	4	02·883	1	89·435	2
16·491	2	02·606	6	89·214	3
16·225	4	02·338	1	89·083	3
15·943	3	02·182	4	88·880	1
15·740	3	01·972	1	88·781	2
15·478	1	01·891	1	88·549	2
15·255	2	01·688	3	88·397	1
15·020	8	01·502	1	88·176	4
14·814	3	01·320	2	87·956	1b
14·573	1	01·016	5	87·725	4
14·267	1	00·857	1	87·491	3
14·080	6	00·701	2	87·305	1
13·694	2n	00·511	4	87·151	1
13·287	8	00·313	2	86·770	2b
13·090	1n	00·179	1	86·620	2b
12·800	4	00·003	1	86·419	1
12·643	1	4299·822	1	86·250	3
12·459	4	99·541	2	85·986	5
12·202	3	99·216	4		
12·019	3	98·951	3		
11·773	3	98·741	1	85·144	4
11·614	1	98·588	1	84·795	3b
11·361	3	98·365	2	84·386	2b
11·158	4	98·235	3	84·169	2b
10·959	1	97·894	2	83·967	4
10·869	1	97·511	2	83·627	3
10·627	4	97·076	3	83·204	2
10·427	4	96·972	5	82·832	2
10·078	5	96·662	3	82·615	1
09·752	4	96·325	1	82·483	3
09·495	4	96·318	3	82·169	2
09·264	1	95·875	5	82·059	2
09·075	3	95·598	3b	81·908	3
08·797	3	95·353	3	81·676	2
08·556	1	95·135	1	81·342	2
08·376	3	94·839	5	81·128	2
07·904	2	94·503	4b	80·798	3
07·795	2	94·310	2	80·626	1
07·470	5	94·164	1	80·480	2
07·250	1	93·895	1	80·253	3
07·122	3	93·768	3	80·107	1
06·888	1	93·484	5	79·909	2
06·680	2	93·039	2	79·561	3b
06·427	1	92·939	4	79·183	2
06·272	1	92·409	3	79·075	2
06·084	5	92·239	3	78·730	2
05·844	2	91·995	3	78·566	2
05·606	1	91·668	2	78·473	1
05·304	4	91·428	3	78·246	4
05·009	4	91·210	1	77·911	2b
04·772	1	91·043	5	77·719	5
04·599	1	90·762	1	77·500	2
04·455	3	90·591	3	77·313	2
04·058	3	90·421	1	76·929	1

Band Spectrum of Sulphur—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4276·758	2	4263·256	4	4250·982	1
76·591	2	63·133	1	49·850	3
76·312	4	62·758	2	49·631	1
76·205	4	62·490	4	49·280	2
75·906	3b	62·212	1	48·921	2
75·658	1	61·966	2	48·655	4
75·522	1	61·759	2	48·479	1
75·297	3	61·407	3	48·215	1
75·087	1b	60·963	2	48·109	3
74·877	2b	60·756	1	48·012	3
74·752	1b	60·639	2	47·817	1b
74·175	4	60·222	2	47·580	2
73·957	2	59·967	1	46·998	2
73·602	1	59·804	2	46·789	3
73·423	3	59·678	3	46·597	2
73·285	3	59·499	2	46·317	2
72·880	1	59·335	1	46·052	1
72·805	1n	59·019	3	45·901	4
72·567	2	58·897	1	45·704	1
72·369	2	58·681	1	45·677	4
72·254	2	58·532	1	45·156	3
71·540	2	58·273	3	45·006	2
71·345	2	58·086	2	44·843	1
71·078	1	57·843	4	44·783	1
70·811	3b	57·616	2	44·566	2
70·511	4s			44·395	1
70·083	2b	57·275	5	44·228	2
69·832	2	57·026	1	43·944	2b
69·623	4	56·944	1	43·725	3
69·432	3	56·699	2b	43·540	2
69·223	1	56·493	2	43·311	1n
68·996	1	56·115	2b	43·201	1n
68·743	1b	55·842	3	42·986	3
68·570	4	55·662	1s	42·733	1
68·239	4	55·580	1s	42·554	2
68·007	1	55·287	3b	42·350	2b
67·846	1	54·953	2	42·081	2
67·676	1	54·815	1	41·901	2
67·411	3b	54·625	2	41·745	3
67·195	1	54·405	3	41·595	1
66·996	1s	54·102	3	41·462	4
66·819	2b	53·960	3	41·192	1
66·400	3	53·282	5	41·068	2
65·986	3	53·108	2	40·835	3
65·913	2	52·884	3	40·583	2
65·685	2	52·594	1	40·339	8
		52·402	1	39·840	3b
65·439	4	52·274	2	39·288	3
65·258	1	52·164	2	38·976	4b
64·991	3	51·962	3	38·769	3
64·784	1	51·643	1	38·557	4
64·565	1	51·510	4	38·187	4
64·329	3n		b	37·894	4
64·141	2	51·273	3	37·608	4
64·029	1	50·795	1	37·402	1
63·892	2	50·679	1	37·164	4
63·671	2s	50·595	2	36·857	5
63·551	1n	50·289	1	36·581	3

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4236·392	2	4223·041	1	4210·943	3
36·234	1	22·810	2	10·758	3
35·812	2	22·667	3	10·659	3
35·766	2	22·480	4	10·453	2
35·625	4	22·221	3	10·324	2
35·363	1	22·150	3	10·139	1
35·058	4	21·966	1	10·006	3
34·629	3	21·811	8	09·745	5
34·358	3	21·592	1	09·519	4
34·164	6 b	21·423	8	09·287	4
33·968	6 b	21·221	1	09·011	5
33·677	1	20·990	8	08·729	5
33·453	3	20·660	2	08·499	3b
33·266	1	20·588	5	08·299	2
33·148	2 b	20·311	8	07·946	6
32·921	2 b	20·074	4	07·702	4
32·766	2	19·881	3	07·525	5
32·415	8	19·647	5	07·311	5
32·100	6	19·411	4	07·144	3
		19·266	3	06·822	5
31·458	4	19·105	2	06·609	3
31·322	2	18·718	4	06·409	2
31·111	4	18·544	4	06·235	3
30·841	4	18·282	8	05·962	4
30·642	2	18·044	3	05·778	2
30·539	1	17·905	1	05·592	4
30·341	6	17·736	5	05·326	6
29·969	8	17·534	2	05·037	2
29·668	1	17·374	1	04·827	5
29·427	1	17·219	4	04·543	5
29·062	8	16·962	1	04·134	2
28·860	3	16·809	4	03·907	4
28·656	4	16·682	5b	03·798	4
28·304	4	16·451	4	03·563	3
28·260	1	16·269	3	03·454	3
28·017	3	16·070	8	03·279	1
27·770	2	15·841	1	03·162	1
27·562	5	15·669	2	03·045	2
27·256	4	15·539	6	02·888	4
26·903	3	15·272	4	02·700	4
26·727	3	15·189	4	02·378	3
26·564	4	14·656	8b	01·910	5
26·446	3	14·106	5	01·514	6
26·344	1	13·799	5	01·291	1
26·142	1	13·513	4	01·184	1
25·920	3	13·186	3	00·986	8
25·745	4	12·990	1	00·553	1
25·434	6	12·796	4	00·423	3
25·087	5	12·646	4	00·205	5
24·887	4	12·404	4	4199·853	4
24·679	1	12·232	4	99·660	3
24·609	1	11·901	3	99·431	3
24·382	4	11·763	2	99·139	3
24·115	4	11·610	2	98·881	2
23·913	2	11·450	2	98·698	1
23·702	5	11·343	2	98·459	6
23·369	5	11·256	2	98·272	4
23·256	4	11·051	3	97·917	4

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4197·730	2	4185·887	3	4174·096	4
97·587	1	85·747	2	73·933	1
97·461	2	85·632	1	73·702	2
97·297	3	85·479	3	73·546	1
97·075	8	85·379	3	73·357	2
96·815	8	85·245	6	73·040	1
96·581	4	84·882	3	72·781	4
96·392	1	84·728	8	72·530	6
96·227	4	84·461	1	72·318	3
96·072	6	84·390	1	72·085	1
95·616	8	84·270	2b	71·918	3
95·347	4	83·846	3	71·755	4
94·968	1	83·713	4	71·549	2
94·862	1	83·478	4	71·337	2
94·697	3	83·330	6	70·955	6
94·482	4		1	70·662	3
94·308	3	83·031	5	70·364	8
94·194	1	82·807	2	70·242	3
94·021	1	82·619	3	69·932	5
93·865	4	82·364	2	69·771	1
93·720	4	82·132	3	69·567	6
93·494	2	81·974	2	69·193	3b
93·274	3	81·761	3s	68·973	3
93·128	1	81·583	2	68·801	4
93·032	1	81·370	5	68·608	1
92·847	3	81·188	2	68·377	1
92·596	4	81·048	2	68·221	6
92·313	4	80·795	4b	67·832	5
92·135	3	80·648	1	67·700	1
91·946	2	80·540	1	67·522	4
91·660	5	80·355	1	67·316	3
91·347	4	80·198	3	67·028	5
91·211	1	79·951	8	66·890	3
90·980	5	79·657	4	66·658	4
90·802	1	79·376	8	66·485	3
90·730	1	78·856	3	66·323	2
90·319	6b	78·696	5	66·200	4
90·131	3	78·322	4	65·916	2
89·907	6	78·184	1	65·683	4
89·716	1	78·102	1	65·473	5
89·552	5	78·031	1	65·270	4
89·283	4	77·718	4	65·146	4
89·039	3	77·536	3	64·956	1
88·816	4	77·389	2	64·807	1
88·614	2b	77·264	1	64·611	3
88·290	5	76·995	2	64·416	3
88·079	2	76·837	6	64·247	6
87·787	5	76·505	3	64·094	4
87·622	5	76·348	6	63·755	4
87·422	3	75·982	3	63·532	4
87·259	1	75·756	6b	63·285	6
87·197	4	75·492	2	62·941	4
86·936	1	75·413	1 b	62·729	3
86·839	4	75·293	1	62·638	3
86·637	3	75·119	4	62·442	1
86·438	2	74·759	4	62·332	5
86·296	4	74·580	5	61·971	1
86·075	4	74·312	4b	61·858	5

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4161·682	1	4150·009	1	4136·701	2
61·572	4	49·890	4n	36·535	3
61·308	1	49·734	3	36·202	3
61·173	4	49·498	1	36·016	2b
60·971	3	49·406	1		
60·880	3	49·205	1	35·854	1
60·734	1	49·042	2	35·672	3
60·559	2	48·905	3	35·175	3
60·377	1	48·595	5	34·987	3
60·199	3	48·227	6	34·755	1
60·034	4	48·051	1	34·570	2
59·781	1	47·897	3	34·359	4
59·670	3	47·671	6n	34·060	2
59·576	3	47·525	6n	33·852	1
59·476	3	47·173	1	33·701	2
59·365	1	47·025	3	33·511	2
59·039	6	46·862	3	33·359	1
58·764	3	46·640	2b	33·268	1
58·631	4	46·469	1	32·923	1
58·223	3	46·311	2	32·714	2n
58·129	3	46·099	3	32·432	3
57·887	4	45·890	1	31·964	3b
57·566	8	45·642	5	31·717	1
57·173	2	45·323	1	31·575	2
56·922	6	45·176	1	31·343	3
56·651	1	45·038	2	31·131	3
56·485	1	44·733	2	30·785	1
56·240	3	44·310	4	30·684	1
56·126	3	43·507	1	30·555	1
55·951	1	43·179	1	30·427	1
55·756	4	43·001	3	30·280	1
55·569	3	42·784	3	30·112	1
55·272	1	42·796	2	29·894	1
55·164	4	42·672	2	29·653	1
55·034	2n	42·397	4b	29·387	3
54·747	2	42·046	2	29·148	1
54·672	3	41·787	3	28·915	2b
54·362	5	41·583	2	28·666	1
53·979	5	41·317	4b	28·539	1
53·709	1	41·138	1	28·406	1
53·497	5	40·911	1	28·262	4
53·168	3	40·701	4	27·939	1
53·009	1	40·389	4	27·795	3
52·818	2	40·017	3 b	27·472	1
52·640	3	39·836	3 b	27·274	2
52·391	3	39·596	2	27·120	1
52·215	3	39·435	2	26·994	1
52·105	3	39·224	2	26·806	2
51·886	3	38·969	3	26·604	1
51·622	4	38·842	4	26·402	1
51·410	3	38·249	1	26·205	1
51·185	1	38·019	2	26·057	1
51·011	2	37·829	1	25·830	2
50·881	2	37·709	1	25·459	3
50·758	1	37·469	5	25·065	3
50·589	3	37·055	1	24·859	2
50·493	3	36·928	2	24·694	2
50·285	4	36·856	1	24·443	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4124·243	3b	4111·037	1	4098·349	5
24·071	1	10·774	4	98·048	3n
23·949	2	10·537	3	97·704	6
23·789	1	10·368	3	97·443	1
23·582	1	10·058	6b	97·262	2
23·457	4	09·722	2	97·095	3
23·298	1			96·905	4
23·109	1	09·109	3	96·634	1
22·863	2	08·839	3	96·433	4
22·721	2	08·514	2	96·095	4
22·565	1	08·322	2	95·972	4
22·146	4	08·026	2	95·728	3
21·881	1	07·801	4	95·332	3
21·541	1	07·595	1	95·184	4
21·352	1	07·493	1	94·941	1
21·098	3b	07·283	3	94·868	1
20·735	3	06·785	8	94·660	4
20·534	2	06·291	2n	94·475	1
20·340	4	06·066	1	94·369	4
20·176	1	05·929	2	93·928	4
20·051	1	05·684	1	93·724	1
19·759	1	05·572	2	93·477	4
19·624	1	05·375	2	93·265	4
19·371	2	05·133	2	93·189	4
18·950	2	05·032	2	92·971	2
18·862	3	04·868	1	92·799	3
18·445	1	04·729	2	92·678	3
18·311	2	04·607	1	92·430	1
18·059	3	04·488	2	92·242	2
17·852	4	04·351	2	91·974	4
17·587	3	04·166	3	91·768	4
17·423	3	03·958	1	91·418	4
17·107	4	03·694	4	91·229	1
16·874	1	03·407	4	91·059	3
16·731	3	03·140	2	90·589	4
16·408	2b	02·973	2	90·493	4
16·084	3	02·755	1	90·302	3
15·760	4	02·585	4	89·954	2b
15·529	3	02·410	1	89·677	2
15·170	3	02·261	1	89·442	1
14·983	1	02·086	3	89·283	3
14·743	2	01·892	1	89·127	4
14·435	3	01·711	3	88·879	3
14·086	6b	01·390	3	88·611	4
13·730	3b	01·199	4	88·355	1
13·448	4	01·000	1	88·205	2
13·208	4	00·743	4	88·092	3
13·031	1	00·484	1	87·807	8
12·895	1	00·264	2	87·547	5
12·640	4	00·063	3	87·333	1
12·411	2	4099·893	1	87·175	4
12·277	1	99·649	1	86·914	4
12·132	1	99·479	3	86·734	4
11·953	2	99·403	3	86·490	4
11·791	3	99·214	3	86·359	4
11·635	3	98·985	4	86·134	3
11·449	1	98·724	4	85·909	2
11·231	3b	98·526	1	85·714	4

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4085·445	8 b	4073·720	1	4060·956	3
85·193	8 b	73·471	3	60·801	2
84·950	1	73·224	1	60·624	3
84·820	2	73·082	3	60·343	5
84·654	2	72·976	1	60·226	3
84·356	8	72·816	3	60·099	1
84·103	3	72·646	3	59·962	1
83·921	1	72·538	3	59·787	6
83·810	3	72·319	2	59·623	2
83·590	5	72·181	2	59·496	2
83·264	5	72·082	1	59·417	2
83·115	3	71·668	4	59·128	3
82·873	5	71·522	1	58·996	2
82·581	5	71·370	3	58·855	3
82·298	4	71·198	4	58·709	4
82·180	4	70·965	4	58·553	5
81·999	4	70·808	3	58·239	5
81·833	2b	70·582	4	58·069	1
81·577	5	70·269	5	57·923	1
81·384	1	70·039	1	57·865	1
81·193	5	69·950	1	57·644	5
80·977	5	69·722	5	57·397	3
80·786	3	69·399	4	57·123	2
80·539	6	69·062	5	56·958	5
80·157	6	68·688	2	56·708	3
79·841	2	68·432	6	56·454	4
79·648	1	68·015	5b	56·331	1
79·506	2	67·810	2	56·046	1
79·375	3	67·675	1	55·883	8
79·197	4	67·529	3	55·676	3
78·950	4	67·355	3	55·580	2
78·870	4	67·132	5	55·325	5
78·621	3	66·838	5b	55·159	3
78·442	3	66·593	5b	54·999	2
78·246	2b	66·279	2	54·794	4
78·084	3	66·009	2	54·609	3
77·887	1	65·893	1	54·435	3
77·792	1	65·521	6	54·296	3
77·693	1	65·447	4	54·157	2
77·581	3	65·259	4	53·896	4
77·437	1	65·060	3	53·768	4
77·170	10	64·916	2	53·523	3
76·754	5	64·733	2	53·304	6
76·497	3	64·524	1	53·162	3
76·400	3	64·372	2	52·964	3
76·194	3	64·201	4	52·844	3
75·963	1	64·067	3	52·639	4
75·745	6	63·373	10	52·482	4
75·555	3	63·181	8	52·220	4
75·373	2	62·933	2	52·029	4
75·208	3	62·757	2	51·900	1
75·076	4	62·514	3	51·631	5
74·877	1	62·286	3	51·386	8
74·793	2	62·197	3	51·178	8
74·601	3	61·961	1	50·925	4
74·379	4	61·727	8b	50·807	4
74·193	4	61·416	2	50·584	4
73·869	1	61·177	4	50·432	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4050·285	4	4038·085	3	4025·847	2
50·065	4	37·915	1	25·699	1
49·812	4b	37·751	1	25·527	1
49·628	4	37·546	4	25·293	5
49·413	3	37·281	6	25·109	5
49·272	1	37·018	1	24·806	1
49·009	5	36·638	1	24·570	5
48·803	1	36·631	3b	24·303	3
48·605	2			24·120	2
48·341	4	36·125	1	23·928	2
48·016	4	35·989	1	23·776	3
47·842	3b	35·910	1	23·692	3
47·699	3	35·783	3	23·459	2
47·448	3	35·675	3	23·240	3
47·303	2	35·413	1	22·975	3
47·144	2	35·147	4	22·794	2s
46·942	3	34·967	2	22·619	4
46·833	3	34·714	4	22·310	4
46·637	3	34·538	1	22·152	3
46·401	4	34·332	4	21·852	4
46·142	4	34·061	5	21·630	1
45·629	3	33·772	5	21·490	3
45·432	1	33·440	5	21·287	1
45·325	1	33·142	4	21·197	2
45·075	5	32·928	4	20·966	3
44·690	3	32·689	3	20·700	4
44·546	3	32·533	2	20·536	2
44·248	3	32·389	4	20·346	3
44·077	2	32·216	1	20·119	2
43·932	2	32·069	3	20·008	2
43·723	2	31·892	3	19·752	2
43·521	2	31·785	1	19·463	2
43·293	2	31·629	1	19·175	1
43·125	2	31·330	4	18·996	1
42·900	1	31·121	4	18·794	1
42·586	2	30·698	4	18·670	2
42·484	2	30·392	5	18·495	2
42·315	5	30·142	3	18·244	3
42·040	1	30·014	3	18·106	1
41·939	1	29·797	3	17·916	1
41·850	1	29·473	3	17·742	1
41·668	3	29·276	3	17·505	1
41·252	6	29·209	2	17·332	3
41·065	1	29·022	2	17·056	2
40·930	2	28·944	2	16·862	1
40·693	3	28·735	4	16·714	2
40·575	3b	28·394	4	16·416	2
40·560	3	28·292	1	16·295	1
40·290	2	28·033	4	16·145	4
40·004	4	27·904	4	15·689	3
39·302	2	27·702	3	15·460	1
39·521	5	27·552	3	15·376	1
39·331	2	27·434	3	15·104	3n
39·062	4	27·283	3	14·833	1
38·859	4	26·991	5	14·743	1
38·620	3	26·743	5	14·519	3
38·330	3	26·369	5	14·337	1
38·296	4b	26·072	5	14·183	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4014·024	1	4002·112	1	3988·550	2
13·600	2n	01·959	1	88·322	2
13·347	2n	01·681	3	87·955	2
13·054	3	01·493	2	87·772	1
12·891	1	01·347	2	87·619	2
12·724	1	01·107	3	87·288	3
12·567	3	00·955	1	87·057	1
12·450	1	00·635	8b	86·891	1
12·283	1	00·286	1	86·749	2
12·161	1b	00·066	2	86·558	2
12·041	1	3999·835	2	86·331	2
11·676	2	99·733	2	86·016	2
11·463	4	99·637	4	85·862	3
11·209	2	99·432	1	85·394	4
11·103	3	99·243	2	85·205	4
10·896	1	99·125	1	84·843	3b
10·792	2	98·925	2		
10·670	1	98·721	5	84·549	1
10·473	1	98·545	1	84·385	1
10·280	1	98·340	3	84·247	4
10·119	2	98·026	3	84·000	2
09·701	2	97·868	1	83·750	2
09·508	2	97·699	2	83·591	1
09·133	2	97·376	2	83·339	2
08·751	5	96·778	2	83·129	1
08·521	2	96·506	2	82·875	4
08·193	4	96·314	2	82·567	4
08·016	3	95·851	2	82·479	2
07·738	1	95·722	2	82·043	3
07·528	3	95·535	2	81·822	3
07·364	3	95·339	2	81·510	4b
07·196	1	95·104	2	81·275	1
07·064	1	94·846	4	80·976	3
06·865	3	94·656	2	80·743	1
06·749	3	94·355	1	80·388	4
06·566	2	94·174	2	80·176	1
06·397	3	93·991	1	79·946	4
06·176	3	93·667	2	79·553	2
05·787	2	93·596	3	79·374	4
05·574	2	93·407	4	79·234	4
05·196	1	93·133	1	78·909	2
05·040	4	92·954	1	78·624	2
04·895	2	92·757	2	78·106	5
04·610	1	92·421	2	77·693	3
04·470	2	92·048	3	77·384	1
04·388	2	91·795	1	77·117	1
04·239	1	91·502	3	76·941	1
04·113	1	91·239	1	76·758	4
03·968	2	91·040	1	76·483	1
03·793	2	90·829	4	76·323	2
03·477	2	90·518	2	76·163	1
03·251	3	90·239	2	75·930	1
03·073	1	89·935	1	75·834	3
02·946	1	89·756	3	75·711	1
02·755	1	89·444	2	75·460	3
02·494	4	89·153	2	75·192	1
02·271	3	89·023	1	75·007	2
02·301	2	88·764	2	74·780	3

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3974·532	1	3962·508	3	3950·158	4
74·386	1	62·176	5	49·849	3
74·212	1	61·891	1	49·609	3
74·034	3	61·759	2	49·489	2
73·716	2	61·615	3	49·258	4
73·516	1	61·307	2	48·961	4
73·322	2	61·162	1	48·687	4
73·190	1	61·019	2	48·502	4
73·012	3	60·857	1	48·364	4
72·808	3	60·678	2	48·139	1
72·584	1	60·579	1	48·009	2
72·321	3	60·398	4	47·735	4
72·131	2	60·243	1	47·491	1
71·907	1	60·119	3	47·336	2
71·762	3	59·931	2	47·201	4
71·542	2	59·806	1	46·740	1
71·282	3	59·707	1	46·502	4
70·929	4	59·497	2	46·350	3
70·710	2	59·387	1	46·111	4
70·504	3	59·260	1	45·844	3
70·191	1	59·097	4	45·606	3
70·008	4	58·898	1	45·540	3
69·816	2	58·794	2	45·164	4
69·736	1	58·557	2	44·937	1
69·529	1	58·303	5	44·752	1
69·268	1	58·014	1	44·648	4
69·072	1	57·843	3	44·350	3
68·955	3	57·665	4	44·136	2
68·489	3	57·393	2	43·826	1
68·375	1	57·144	4	43·548	4
68·245	1	56·965	3	43·311	4
68·096	1	56·363	3	42·567	4
67·938	2	56·161	1s	42·144	4
67·721	2	55·954	1s	41·641	4
67·548	2	55·700	4	41·304	1
67·280	3b	55·461	1	40·765	2b
67·072	3	55·203	4	40·446	5
66·818	2	54·943	4	40·162	1
66·631	2	54·755	1	39·808	4
66·450	3	54·404	4	39·358	5
66·257	2	54·179	2	38·875	1
66·083	2	54·069	2	38·762	1
65·892	4	53·912	1	38·485	3
65·714	1	53·782	2	38·279	1
65·511	4	53·608	3	38·051	2
65·294	2	53·495	1	37·425	3
65·153	2	53·309	1	37·164	3
64·777	3	53·129	3	36·673	4
64·553	4	52·908	3	36·278	3b
64·385	1	52·647	1	35·878	2
64·248	3	52·308	2	35·460	5
63·937	3s	52·071	2	35·155	3
		51·837	2	34·916	3b
63·602	1	51·500	3	34·535	2
63·435	4	51·206	3	33·932	4
63·481	4	50·978	2	33·685	1
63·077	1	50·673	4	33·249	2b
62·789	3	50·329	4	32·432	5b

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3931·947	2	3911·050	3	3889·050	2b
31·712	3	10·911	2	88·524	2b
31·416	1	10·624	1	88·121	2
31·078	1	09·914	4	87·647	3
30·874	1	09·148	1	86·839	3
30·559	2	08·846	4	86·036	2b
30·237	1	08·570	3	85·750	5
30·106	2	08·343	3	85·399	3
29·691	3	07·531	3	85·183	2
29·461	1	07·127	4	84·873	2
28·856	4b	06·841	1	84·584	1
28·403	2	06·634	1	84·332	3
27·573	2	06·285	4	84·065	2
27·274	2	05·702	3	83·828	1
26·953	4	05·497	3	83·214	3
26·354	1	05·126	4	82·697	3
26·111	3	04·684	1	82·429	5
25·837	2	04·477	3	82·172	1
25·272	2	04·157	6	81·919	2
25·042	2	03·819	1	81·433	6
24·802	2	03·298	1	81·016	2
24·415	2	02·827	1	80·518	1
24·178	2	02·362	4b	80·306	1
23·903	1	01·842	1	80·123	1
23·733	3	01·622	1	79·860	2
23·288	1	01·432	4	79·635	2
22·813	1	00·762	5	79·325	5
22·114	5	00·437	3	78·660	3
21·580	1	00·181	3	77·925	1
21·363	1n	3899·753	6	77·365	4b
21·013	1	99·244	2	76·982	2
20·887	2n	98·864	3	76·560	2
20·456	4	98·606	2	76·103	2
20·047	4	98·248	1	75·707	2
19·577	5	98·023	1	75·378	2
19·022	3	97·724	3	74·587	1
18·760	2	97·310	1	74·091	4
18·369	3n	97·021	2b	73·670	2b
18·198	1n			73·249	2
17·904	1	96·527	2	72·888	1
17·542	2n	96·109	3	72·316	1
17·389	1n	95·574	2	72·064	2
17·046	2	95·165	2b	71·761	1n
17·834	1			71·115	3
16·527	3b	94·601	3	70·816	1n
15·966	2b	94·202	3	70·501	3
15·322	3	93·743	1	70·275	2
14·906	2b	93·566	1	69·951	1
14·683	2b	93·323	3	69·766	1n
14·337	1b	93·097	1	69·156	1n
13·944	2b	92·815	1	69·037	3
13·406	4	92·565	2	68·645	4
13·153	2	91·715	2	68·104	3
12·771	1	91·434	1	67·509	3
12·546	2	91·230	1	66·917	3
12·212	4	90·984	3s	66·415	4b
11·920	1	90·460	3	65·486	1s
11·661	5	90·104	2	65·219	2b
11·408	1	89·786	2	64·849	2

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3864·566	2	3840·021	3s	3814·984	1b
64·233	1	39·702	1n	14·573	1b
63·859	2	39·174	2	14·074	1
63·143	4	38·868	1	13·896	1
62·480	2b	38·366	2	13·542	3
62·091	5	38·253	2	12·881	4
61·490	2	37·914	1n	12·467	1
61·218	2	37·396	2b	12·337	1
60·858	2			12·041	3
60·516	3	37·017	3s	11·645	2
59·787	5s	36·758	1	11·330	4
59·102	2	36·530	2	10·704	3b
58·366	2b	36·088	3		
57·750	4	35·668	2	09·851	2
57·457	2	35·506	2n		
		35·204	1	09·274	3
56·312	1	34·901	3	08·880	3
56·017	2	34·157	1s	08·592	1
55·810	3	33·798	1n	08·377	1
55·428	3	33·505	2b	07·748	2
54·822	1	33·096	1	07·365	3
54·599	1	32·883	1	07·017	2
54·281	1	32·630	1	06·694	2
54·100	3	32·407	1	06·414	2b
53·686	3	32·135	1	05·821	2b
53·392	2b	31·884	2	05·186	3
53·145	1	31·497	1b	04·844	3
52·917	3	30·975	2	04·423	1
52·590	2	30·569	1	04·136	1
52·300	3	30·269	2	03·676	2
51·874	3b	29·398	1b	03·429	3
		29·073	1b	03·073	2
51·752	1	28·484	2b	02·421	3
51·271	3	27·437	1	01·903	1
51·004	2	27·152	1	01·645	3
50·664	1b	26·831	3	01·199	2
50·395	2	25·412	1	00·716	2b
49·499	4	25·174	2b	00·252	1b
49·183	1	24·563	4	3799·893	2b
48·878	3b	23·727	2	99·059	2
48·011	2b	23·537	2n	98·354	2
		22·964	3	97·559	1b
47·666	1	22·200	2	97·203	1
47·259	2	21·947	1	96·889	2
46·291	3	21·481	1	96·362	1
46·023	2	21·090	1	96·128	2
45·770	2	20·881	1	95·716	2
45·300	3b	20·188	1	95·390	1
44·988	1	19·881	1	94·618	3
44·718	3	19·559	1	94·176	1
44·390	1	19·201	2	93·914	2
44·095	4	18·954	2	93·564	1
43·471	2	18·528	1	93·300	2
43·250	2	18·323	1	92·841	4
42·689	1	17·796	3	92·451	1
42·538	2	16·986	3	92·072	3
42·277	1	16·626	2s	91·713	4
41·911	3b	15·569	2	91·400	2
40·905	4	15·168	3b	91·055	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3790·860	2	3769·651	3	3748·054	4
90·554	3	69·472	6	47·456	4
89·972	3	69·215	1	46·998	6
89·670	4	68·996	2	46·047	3
89·386	2b	68·583	2	45·429	2
89·096	1	68·233	3	44·749	2b
88·880	3	67·526	3	44·500	1
88·476	3	66·921	3	44·186	2b
88·202	1	66·670	2	43·782	2
87·843	1	66·358	2	43·432	2
87·466	2	65·884	3b	42·977	2
87·159	3	65·723	2	42·489	3
86·839	2	65·476	2	41·999	3
86·639	3	65·029	4b	41·515	3
86·143	1	64·717	1	41·217	2
85·818	4b	64·321	2	40·858	3
85·321	4	63·736	2	40·099	3
85·117	3	63·546	1	39·885	1
84·668	1	63·032	2b	39·617	2
84·454	1			39·157	2
83·946	2	62·667	2	38·941	2
83·577	1			38·667	2
83·342	1b			38·453	2
83·085	2	61·920	3	38·120	2
82·519	2	61·646	3	37·968	2
82·030	1b	61·249	3b	37·373	3
81·779	1	60·966	1b	36·744	3
81·511	1	60·751	3	36·080	1
81·280	3	60·505	2	35·449	2
80·451	1	60·194	3	35·014	2
80·163	3	60·006	3	34·712	2
79·902	1	59·748	2	34·253	3
79·605	3	59·426	1	33·794	2
79·454	3	59·211	1	33·128	2
78·743	2	58·871	4b	32·782	1
78·447	2	58·099	1	32·538	2
78·103	2	57·815	1b	32·033	3
77·818	1	57·502	1	31·756	1
77·367	2b	57·202	4s	31·573	1
77·028	1	56·768	2	30·971	2
76·582	4	56·280	3b	30·661	4
76·307	1	55·941	1	30·067	2
75·542	2	55·542	4	29·845	1
75·262	2	55·115	1	29·611	1
74·795	3	54·854	2	29·293	3
74·240	2b	54·567	1	29·068	1
73·983	1	54·026	4	28·533	4b
73·655	1	53·722	3		
73·361	3	53·385	3	28·089	1
72·913	3r	52·473	4	27·819	2
72·422	2	51·911	3	27·314	2
72·085	2	51·262	3	27·051	1
71·717	2	50·873	4	26·613	3
71·311	1n	50·498	1	26·079	2
70·777	3	50·175	5	25·888	1n
70·524	2	49·536	2	25·348	1
70·273	1n	49·284	3	25·100	2
		49·023	1	24·785	2
69·768	3	48·731	6	24·569	1

BAND SPECTRUM OF SULPHUR—*continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3724·345	2	3694·703	1b	3667·340	2
23·368	2n	94·643	1b	67·067	1
22·999	2s	94·138	3b	66·899	1
22·089	2b	93·790	1b	66·537	2
21·691	3	93·499	1b	66·217	4
21·043	1	93·086	2n	66·130	1
20·500	1	92·642	3n	65·695	1
19·438	1n	91·836	3n	65·285	2
19·149	1s	91·400	1n	64·990	2
18·847	3	91·095	2	64·689	2
18·518	2	90·872	2	64·418	2
18·246	1	90·552	1	64·080	2
17·178	2	90·267	2	63·756	2
16·565	2	90·059	2	63·473	2
15·885	2	89·610	2b	63·345	1
15·448	2	89·208	2n	62·877	1b
15·137	1	87·010	1n	62·656	2s
14·755	3b	86·585	1n	62·437	3n
14·484	2	86·134	2	62·276	2
13·807	2	85·779	1	61·614	1
13·551	3	85·457	1	61·307	1
12·747	2	84·943	2	61·023	1
12·417	2n	84·518	3	60·478	2s
11·967	2	83·896	1	60·253	2s
11·404	3	83·595	1	60·019	1b
11·112	1	83·225	2	59·656	2
10·818	2	82·547	1n	59·075	3
10·573	1	81·632	1n	59·706	2
10·322	2	81·203	2n	58·508	1
09·716	4	80·939	1n	58·295	2s
08·924	2	80·255	1	57·991	3
08·177	1	79·302	2	57·547	2
07·622	2	78·997	3	57·068	2
07·442	1	78·446	1	56·852	1s
06·786	1	77·806	1	56·573	3
06·590	1n	77·405	1s	56·159	2b
06·177	1n	77·073	2	55·754	3b
05·306	2s	76·826	1	55·220	5b
04·444	1	76·271	2	54·842	4
03·870	2	75·874	1	54·334	2
03·220	1	75·644	2	54·105	2
02·513	2	75·233	3	53·838	2
02·361	2	74·055	3	53·602	2
02·022	1b	73·517	2	53·300	2n
00·696	2	73·042	2	53·096	2n
3699·907	1	72·717	1n	52·834	1
99·604	3	72·377	2	52·536	1
99·038	1	71·894	2	52·274	1
98·779	2	71·632	2	52·074	2
98·553	1	71·185	1s	51·583	3
98·147	2s	70·762	3n	51·200	1
97·491	2s	70·333	3	50·537	5
96·955	2	70·153	1	50·084	2
96·264	2	69·197	3	49·325	1b
96·040	1	68·701	1n	49·067	4
95·450	2	68·466	1	48·838	3
95·235	3n	67·951	3	48·516	2
94·976	2	67·634	2n		

The Stereochemistry of Nitrogen. *By* H. O. Jones, *M.A., D.Sc.*

[Ordered by the General Committee to be printed *in extenso*.]

The stereochemistry of nitrogen has, for a number of years, attracted considerable attention, which was until recently confined chiefly to the isomerism of the tervalent compounds; of late years, however, the quinquevalent compounds have been the subject of an exceptionally large number of investigations. The former, with the exception of a few outstanding problems, may almost be regarded as a closed chapter, whereas the latter is still in a state of rapid change. The phenomena exhibited by these compounds are so bewildering in their variety, and apparently so difficult to reconcile with one another, that this brief review of the present state of our knowledge may be useful in promoting discussion which will throw some light on the obscure problems that perplex workers in the field.

The facts brought to light by the work on quinquevalent nitrogen compounds considered in conjunction with those observed by Professor Pope and his collaborators in sulphur and selenium compounds necessitate some slight alteration in the prevalent conception of valency, and have at the same time supplied the materials for such a revision of ideas.

No entirely satisfactory hypothesis as to the nature of valency and the forces which act in chemical compounds has hitherto been proposed. There is, however, a growing conviction that these forces are electrical in their origin and arise in consequence of the electrical structure of the atom; if this be so, then these forces are very probably localised along certain directions outside the atom.

However, without making any assumption as to the nature of these forces, the existence and stability of chemical compounds almost require that they should have a definite spatial configuration such as must be assumed in order to account for the phenomena of stereoisomerism, and further, that the most symmetrical configuration possible would probably be the most stable. By a definite stable configuration is understood an arrangement of atoms or groups around a plurivalent atom in which each group, under the action of forces exerted on it by the plurivalent atom and by the other groups, oscillates (within limits dependent on temperature and other conditions) about an equilibrium position in which it would probably be stationary at absolute zero. The lines joining the centre of the plurivalent atom to the centres of the various atoms or groups in their equilibrium positions may be called the 'valency directions.' The equilibrium position for any particular radical attached to a plurivalent atom—carbon, for example—would not be fixed, but would be dependent to some extent on the other radicals attached to the same atom, since the position taken up is the result of the action of a number of forces; hence the valency direction must also be variable to some extent. These views were quite clearly expressed by van't Hoff soon after the tetrahedral configuration for carbon compounds was proposed.

The new assumption, which had to be made in the light of recent experience, is that during a change of valency, such as that of sulphur from quadri- to sexa-valency,[1] the configuration of the molecule may alter and the radicals already present take up entirely new positions.

[1] Pope and Neville, *Trans. Chem Soc.*, 1902, **81**, 1560.

Assumptions of a slightly different kind have been made to account for certain phenomena observed in quinquevalent nitrogen compounds; it has been found necessary to suppose that the position occupied by the electro-negative radical is not always the same—in fact, that the resultant effect of the forces exerted by the nitrogen atom and four electro-positive radicals is such as to attract an electro-negative radical which may enter the molecule in one of two positions.

Further, in order to account for the existence of one kind of isomerism observed among tervalent nitrogen compounds (p. 172), it has been suggested that for three groups attached to a nitrogen atom two configurations are possible.

Stress must be laid on a difficulty encountered in the whole of this field—namely, the uncertainty as to the cause of certain differences which are observed in some compounds, particularly when those differences disappear on solution, whether they are to be attributed to isomerism of an unstable kind or merely to dimorphism: this difficulty is accentuated when the compounds exhibit no distinctive differences in their chemical reactions.

It has been deemed advisable in dealing with this subject to treat the tervalent and quinquevalent nitrogen compounds separately, and in the latter case to present the facts completely before entering upon any discussion of them, because it is necessary to review the whole field in attempting to offer a consistent explanation of the various phenomena. The time is certainly not yet ripe for drawing any final conclusions about this complicated subject, and there is still much work to be done before a clear path through the maze will become evident.

I. Tervalent Nitrogen Compounds.

(i) *Compounds of the type* N *a b c*.

(*a*) *The Problem of Optical Activity.*—It might be expected from purely dynamical considerations that the most stable configuration for three groups attached to one atom (nitrogen) would be that in which all three groups were situated in the same plane with that atom; the distances of the groups from the centre of the nitrogen atom would be variable and dependent on the nature of the groups, but no displacement out of the plane would be expected so long as none of the groups was asymmetric. Such a displacement apparently occurs when strain is introduced, as in the formation of cyclic compounds or double linkages, and might occur if one of the groups became asymmetric.

This view is supported by the facts, since all attempts to demonstrate asymmetry in tervalent nitrogen compounds—other than cyclic compounds—have hitherto been abortive.

Krafft[1] tried to resolve ethyl-benzylamine and *p*-tolyl-hydrazine by the crystallisation of their neutral tartrates; Behrend and König[2] made similar experiments with the tartrates and mandelates of β benzyl-hydroxylamine and β nitro-benzyl-benzyl-hydroxylamine, and Ladenburg[3] on the acid tartrates of methylaniline, tetrahydroquinoline, and tetrahydropyridine. In all cases the salts appeared to be homogeneous, their properties remaining unaltered by recrystallisation.

Regarded in the light of recent experience these experiments are

[1] *Ber.*, 1890, **23**, 2780.
[2] *Ann.*, 1891, **263**, 175.
[3] *Ber.*, 1893, **26**, 864.

inconclusive, since similar attempts failed to resolve quinquevalent nitrogen compounds. The failure might have been due either to hydrolytic dissociation of these salts of weak acids with weak bases, or to partial racemism, which the recent work of Professor Kipping has shown to occur so frequently.

Reychler [1] eliminated the first-mentioned possible cause of failure in his attempts to resolve methyl-ethyl β naphthylamine by fractional crystallisation of its dextro-camphorsulphonate from non-hydroxylic solvents; the writer also made a similar attempt with methyl-benzyl aniline, but no resolution was effected in either case.

The evidence derived from all the foregoing experiments (with the exception of that in which *p*-tolyl-hydrazine was used) is useless if the change of valency direction established in the case of sulphur and selenium also occurs in nitrogen during the change from ter- to quinquevalency. There is, however, no evidence of this, and the ease with which cyclic compounds, such as pyridine and piperidine, form quaternary ammonium derivatives is not in favour of this view.

On this account some experiments were made by Mr. J. P. Millington and the writer [2] with the object of obtaining evidence free from this objection, by avoiding a change in the valency of the nitrogen during the process of resolution. Benzyl-phenyl-hydrazine *d*-camphorsulphonate and the brucine salt of methyl-ethyl aniline sulphonic acid were submitted to fractional crystallisation, but without effecting any separation into fractions of different rotatory power; in the first case it is probable that no change of valency of the nitrogen atom in question takes place, and in the second it is certain.

Evidence of quite a different kind has been adduced by Messrs. Kipping and Salway.[3] It was proved that when an externally compensated acid chloride reacted with an externally compensated primary amine (each containing an asymmetric carbon atom) to form a substituted amide, this consisted of four compounds, which being enantiomorphously related in pairs give rise to two externally compensated compounds easily separable by fractional crystallisation. This, therefore, forms a method of testing for asymmetry in carbon compounds, and by analogy it should be capable of detecting asymmetry in nitrogen compounds. The products of the interaction of *dl*-benzyl-methyl-acetyl chloride with methyl aniline, *p*-toluidine, phenyl-hydrazine and benzyl aniline were examined and found to be homogeneous. The active (*d*) acid chloride was also allowed to react with *p*-toluidine and with benzyl aniline; but, as before, the product appeared to be a chemical individual. Finally, the active chloride was treated with an active amine; if the nitrogen atom form a centre of asymmetry, in addition to the two already present, then two compounds should be formed; but again the product was homogeneous.

Clearly, therefore, all the evidence is in favour of a plane configuration for tervalent nitrogen compounds.

(*b*) *Isomeric Tervalent Nitrogen Derivatives* N *a b c*.—Although the tervalent nitrogen atom is incapable of giving rise to optical activity, it seems capable of giving rise to another kind of isomerism of which there are two distinct examples.

[1] *Bull. Soc. Chem.*, 1902[3], **27**, 979.
[2] *Proc. Camb. Phil. Soc.*, 1904, xii. 489.
[3] *Trans. Chem. Soc.*, 1904, **85**, 438.

Miller and Plöchl [1] found that the product of the interaction of *as*-m-xylidine with acetaldehyde in hydrochloric acid solution was a mixture of substances which had to be separated mechanically. The two substances have the same composition and molecular weight and give the same reactions. They are represented by the formula

$$\begin{array}{l} C_6H_3(CH_3)_2NH\text{—}CH\text{—}CH_3 \\ \qquad\qquad\qquad\quad\; CH_2 \\ \qquad\qquad\qquad\quad\; CHO \end{array}$$

because (1) they give the tests for an aldehyde, (2) condense with m-xylidine to give the same product,

$$\begin{array}{rl} C_6H_3(CH_3)_2NH\text{—} & CH\text{—}CH_3 \\ & \;| \\ C_6H_3(CH_3)_2N{=}CH\text{—} & CH_2, \end{array}$$

(3) give the same benzoyl derivative, and (4) are mutually transformable. They differ only in melting point (102° C. and 131° C)., crystalline form, and solubility in ether and benzene. The evidence points very clearly to some cause other than structural differences to account for this kind of isomerism, though the possibility of tautomerism has not been definitely excluded.

The other example was observed by Willgerodt [2] in the *sym*-dinitro-phenyl-phenyl-hydrazine produced by the interaction of dinitro-chlorbenzene and phenyl-hydrazine. Two isomeric substances appear to be formed, one being an amorphous powder which is readily transformed into the other and crystalline isomeride. Here also the possibility of structural difference in the nitro group hardly exists, for if it did, it would certainly be observable in many other compounds. Willgerodt offers an explanation of this isomerism based on the assumption that free rotation is limited between two nitrogen atoms; but this assumption is undesirable and is not supported by any other experimental facts.

Vaubel [3] suggested a configuration for the nitrogen atom which would explain the above cases of isomerism, based on the following considerations: a nitrogen atom is capable of taking the place of a —CH group in pyridine and also of becoming quadruply linked to carbon in isocyanides. On this view the groups attached to the nitrogen are supposed to occupy definite fixed positions which are at certain different but fixed distances from the centre of the nitrogen atom. This assumption is unnecessary and is contrary to the spirit of stereochemical conceptions.

Further work on this subject is much needed, but if it be definitely established that isomerism, such as that apparently exhibited by the above-mentioned substances, does exist, then it must be assumed that there are two possible positions of equilibrium for three groups attached to a nitrogen atom, one being somewhat more stable than the other. Isomerism, due to such a cause, could only be detected under favourable circumstances similar to those under which these experiments were carried out—namely, when a reaction resulting in the formation of a solid substance takes place in the cold; in all such cases one isomeride would probably readily pass into the other.

[1] *Ber.*, 1896, **29**, 1462.
[2] *Journ. prakt. Chem.*, 1888, **37**, 449.
[3] *Stereochemische Forschungen*, 1899, i. 20.

(ii) *Cyclic Nitrogen Compounds.*

The evidence for isomerism of tervalent nitrogen compounds is more conclusive in those cases where the nitrogen atom forms part of a ring.

Ladenburg [1] found that when coniine hydrochloride was distilled with zinc dust and a little water a new substance called isoconiine was produced; isoconiine differs from coniine in optical rotatory power, the solubility of its chlorplatinate in alcohol and ether, and to a less degree in other properties.

The existence of these isomerides is explained by supposing that the hydrogen atom attached to the nitrogen may be either on the same side of the plane of the piperidine ring as the propyl group or on the opposite side, thus:

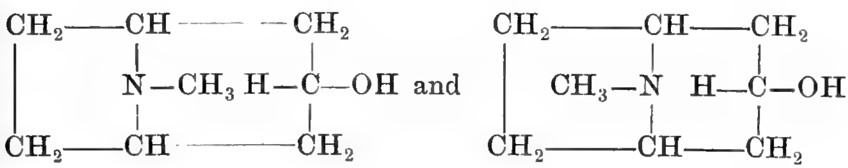
This hypothesis is not incompatible with the plane configuration of the nitrogen atom, since the strain introduced by the formation of a ring may disturb the equilibrium.

Later [2] Ladenburg described *iso*stilbazoline, an isomeride of stilbazoline differing from it chiefly in rotatory power. Isomerism of this kind should exist in the γ piperidine compounds which are not optically active, but this has never been demonstrated.

The case is, however, much strengthened by the discovery of the isomerism of tropine and ψ tropine.

ψ tropine was obtained by Ladenburg and Roth [3] from hyoscine, and was prepared artificially by Willstätter [4] by the reduction of tropinone. Similarly, Willstätter and Müller [5] obtained two tropylamines.

In these cases there is no asymmetry in the molecule; both compounds are inactive, and the isomerism can only be explained by the different spatial relations of the methyl and the hydroxyl or amino group thus—



Giustiani [6] described isomeric benzylmalimides which differ in solubility and melting point, and give different monacetyl and benzoyl derivatives. Here, however, there is a possibility of tautomerism which has not been excluded, but if this be set aside the isomerism could be explained in the same way as that described above.

[1] *Ber.*, 1893, **26**, 854.
[2] *Ber.*, 1903, **36**, 3694.
[3] *Ber.*, 1884, **17**, 151.
[4] *Ber.*, 1896, **29**, 936.
[5] *Ber.*, 1898, **31**, 1212, 2655.
[6] *Gazz.*, 1892, **22**, 1. 169; 1893, **23**, 1. 168.

(iii) *Isomerism in compounds of the type* $\begin{array}{c} a\text{—C—}b \\ \| \\ \text{N—}c. \end{array}$

The isomerism among compounds in which nitrogen is doubly linked to carbon is now so well established and the hypothesis of Hantzsch and Werner to explain it so abundantly supported by experimental evidence, that in this place it will suffice if a very brief statement of the most important conclusions arrived at be made, and attention called to a few points which cannot as yet be regarded as settled satisfactorily.

(*a*) *Ketoximes.*—Goldschmidt[1] while working with V. Meyer on the oximes of benzil discovered an isomeride of benzil dioxime; later V. Meyer and Auwers discovered a third modification of the same substance[2] and a second monoxime of benzil.[3] Meyer and Auwers gave a clear and conclusive demonstration of the structural identity of these oximes[4] and proposed to account for their existence by assuming that free rotation between the carbon atoms was prevented in these compounds. The discovery of an isomeric oxime of *p*-chlor-benzophenone[5] disposed of this view, which cannot account for the existence of a second oxime, and the hypothesis of Hantzsch and Werner[6] alone remained.

These authors explain the isomerism of oximes by supposing that when a nitrogen atom is united to carbon by a double bond, the third valency is not in the same plane as the other two, and the group attached to it may take up two equilibrium positions one on either side of this plane.

According to this hypothesis, there should be one oxime of

$$\begin{array}{c} a \\ a \end{array}\!\!>\!\text{CO namely} \begin{array}{c} a\text{—C—}a \\ \| \\ \text{N—OH} \end{array}$$

$$\text{and two of } \begin{array}{c} a \\ b \end{array}\!\!>\!\text{CO namely} \begin{array}{c} a\text{—C—}b \\ \| \\ \text{NOH} \end{array} \text{ and } \begin{array}{c} a\text{—C—}b \\ \| \\ \text{HON,} \end{array}$$

a prediction verified for the oximes of benzophenone and *p*-chlor-benzophenone and in many other cases.

Then two monoximes and three dioximes of a diketone $\begin{array}{c} a\text{—C—C—}a \\ \|\quad\| \\ \text{O}\quad\text{O} \end{array}$ should exist, the dioximes being represented thus:

$$\begin{array}{c} a\text{—C—C—}a \\ \|\quad\;\| \\ \text{HO N}\;\;\text{N.OH} \end{array} \qquad \begin{array}{c} a\text{—C———C—}a \\ \|\qquad\quad\| \\ \text{HO N}\quad\text{HON} \end{array} \qquad \begin{array}{c} a\text{—C————C—}a \\ \|\qquad\quad\;\| \\ \text{N OH}\quad\text{HON,} \end{array}$$

which has been verified in the case of the mono- and dioximes of benzil.

The isomerism in all these cases is perfectly definite, the compounds differing in melting point, crystalline form, solubility, and some of their chemical reactions, and further are mutually transformable under the influence of heat, solvents, and suitable reagents such as acids and alkalies.

The usual criterion for determining their configurations is the

[1] *Ber.*, 1883, **16**, 2176. [2] *Ber.*, 1889, **22**, 537. [3] *Ber.*, 1889, **22**, 705.
[4] *Ber.*, 1888, **21**, 784, 2510; 1889, **22**, 564, 1985, 1996.
[5] *Ber.*, 1890, **23**, 2403. [6] *Ber.*, 1890, **23**, 11; *Zeit. phys. Chem.*, **10**, 1.

'Beckmann transformation,'[1] by which the oximes are transformed into substituted acid amides, thus :—

$$\begin{array}{c} a{-}C{-}b \\ \| \\ N{-}OH \end{array} \longrightarrow \begin{array}{c} a{-}C{=}O \\ | \\ NH{-}b \end{array} \quad \text{and} \quad \begin{array}{c} a{-}C{-}b \\ \| \\ HO{-}N \end{array} \longrightarrow \begin{array}{c} O{=}C{-}b \\ | \\ a.HN \end{array}$$

The hypothesis predicts four isomerides of compounds of the form $\begin{array}{cc} a{-}C{-}{-} & C{-}b \\ \| & \| \\ HON & NOH \end{array}$ but until quite recently no instance of this had been observed. Manasse[2] obtained three dioximes of camphorquinone, and Dr. Forster[3] re-examined these and obtained a fourth.

In the case of the ketoximes the predictions of the hypothesis have been experimentally verified for all kinds of ketones of the aromatic but not for those of the fatty series. Most of the attempts to get isomeric oximes of fatty aldehydes and ketones have been unsuccessful ;[4] the only case definitely observed is that of the oximes of oxalacetic acid,[5] of which there are two definite isomers differing in melting point and in their behaviour towards ferric chloride ; with which the α acid gives a yellowish brown and the β a violet colour.

(*b*) *Aldoximes* —The case of the aldoximes cannot be regarded with the same complacency. Beckmann[6] observed that benzaldoxime when treated with sulphuric acid or with an ethereal solution of hydrogen chloride was converted into an isomeride. A long controversy then ensued between chemists who claimed that the isomerides were structurally different, as represented by $C_6H_5CH{=}NOH$ and $C_6H_5CH\langle\begin{array}{l} NH \\ | \\ O \end{array}$, and those who held the view that the differences were stereochemical, as in the case of the ketoximes. The work has been confined mainly to benzaldoxime and substituted benzaldoximes. The two benzaldoximes give respectively an oxygen and a nitrogen ester when treated with alkyl haloid compounds—a fact regarded as evidence in favour of structural isomerism. The work of H. Goldschmidt[7] on the action of phenyl*iso*cyanate on the two oximes and that of Professors Hartley and Dobbie[8] on their absorption spectra, however, is in favour of structural identity.

The hypothesis of stereoisomerism is now almost universally accepted, and is supported by the phenomena exhibited by the esters, which were at first so difficult to reconcile with this view.

Beckmann[9] treated α (*anti*) benzaldoxime with sodium ethylate and benzyl chloride in the cold and obtained an oily ester which on treatment with hydrochloric acid split up partially into benzaldehyde and α benzylhydroxylamine and was therefore an oxygen ester, whereas by similar treatment of the β (*syn*) oxime he obtained a crystalline ester which

[1] *Ber.*, 1883, **16**, 2176.
[2] *Ber.*, 1893, **26**, 243.
[3] *Trans. Chem. Soc.*, 1903, **83**, 514.
[4] Franchimont (*Rec. trav. Pays-Bas*, 10, 236); Dunstan and Dymond, *Trans. Chem. Soc.*, 1892, **61**, 470 ; 1894, **65**, 206.
[5] Piutti (*Gazz.*, 1888, **18**, 457); Ebert (*Ann.*, 1885, **229**, 76) ; Cramer (*Ber.*, 1891, **24**, 1206); Dollfus (*Ber.*, 1892, **25**, 1915); Fenton and Jones (*Trans. Chem. Soc.*, 1901, **79**, 95).
[6] *Ber.*, 1887, **20**, 2766 ; 1889, **22**, 429.
[7] *Ber.*, 1889, **22**, 3112.
[8] *Trans. Chem. Soc.*, 1900, **77**, 509.
[9] *Ber.*, 1889, **22**, 435, 1534.

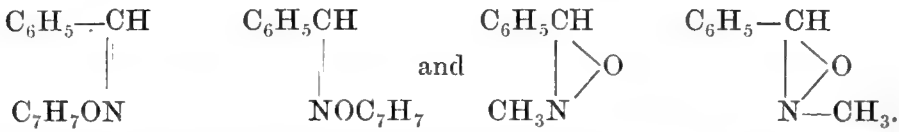
gave β benzyl-hydroxylamine on hydrolysis, and was therefore a nitrogen ester.

Later Werner and Buso [1] found that the liquid oxygen ester just referred to, on treatment with hydrochloric acid underwent isomeric change during its partial hydrolysis, and gave rise to a solid oxygen ester. There are consequently two isomeric oxygen esters, the existence of which can only be explained by different steric relations, and a nitrogen ester.

The phenomena exhibited by the methyl esters are complementary to those observed in the benzyl esters. Petraczek [2] prepared a methyl ester by the action of sodium and methyl iodide on α benzaldoxime, which ester when hydrolysed gave α methyl-hydroxylamine. H. Goldschmidt and Kjellin [3] isolated an ester from the products of the interaction of β benzaldoxime, methyl iodide, and sodium methylate, which gave β methyl-hydroxylamine on hydrolysis, and was therefore a nitrogen ester; at the same time they observed the odour characteristic of the oxygen esters and concluded that the oxygen ester of the *syn* oxime was formed at the same time.

Finally Dr. Luxmoore [4] observed that by the action of methyl bromide and hydrobromic acid on β benzaldoxime the hydrobromide of a new nitrogen ester was produced. This ester differed from the nitrogen ester already known in being very readily hydrolysed by water to form β methyl-hydroxylamine; it was also labile, and on standing changed into the stable *syn* N ester.

Thus there is enough evidence to justify the conclusion that two benzyl-oxygen esters and two methyl-nitrogen esters exist, and the isomerism in these cases can only be explained on the hypothesis of stereoisomerism—thus,



This conclusion is supported by Goldschmidt's work on isomeric oxygen esters of anisaldoxime and nitro-benzaldoxime.[5]

The isomerism of the nitrogen esters is analogous to that of tropine and ψ tropine.

In addition to the Beckmann transformation a second criterion for the determination of configuration is applicable to the aldoximes; one of the oximes on treatment with acetic anhydride loses water and gives a nitrile, whereas the other either remains unchanged or gives an acetyl derivative, the former must therefore be the *syn*-oxime, $\begin{array}{c}a\text{—C—H}\\ \Vert\ \ \ \ \\ \text{NOH}\end{array}$, and the latter the *anti*-oxime, $\begin{array}{c}a\text{—C—H}\\ \Vert\ \ \ \ \\ \text{HON}\ \ \ \ \end{array}$.

The hypothesis of Hantzsch and Werner, which has, as we have seen, accounted in a satisfactory manner for the isomerism observed among the oximes, requires that isomerism should exist also in other compounds with

[1] *Ber.*, 1895, **28**, 1278. [2] *Ber.*, 1882, **16**, 827. [3] *Ber.*, 1891, **24**, 2812.
[4] *Trans. Chem. Soc.*, 1896, **69**, 177. [5] *Ber.*, 1890, **23**, 2178.

a like structure. A search for these isomerides instituted by Hantzsch and others has been successful in a number of cases. In all these cases it is more difficult to exclude the possibility of dimorphism and to show that the compounds in question are structurally identical.

(*c*) *Hydrazones and Semicarbazones.*—The evidence for the existence of isomerism among hydrazones and semicarbazones is fairly conclusive, though by no means so satisfactory as for the oximes.

Fehrlin [1] found that the hydrazone of *o*-nitro-phenyl-glyoxylic acid was converted into an isomeride, when dissolved in alkalies and precipitated by the addition of acids; the two products differed in crystalline appearance, melting point, solubility, and behaviour with nitric acid, but gave the same reduction product. These results were confirmed by Krause,[2] who found, besides, that both gave hydrazones of isatin on oxidation.

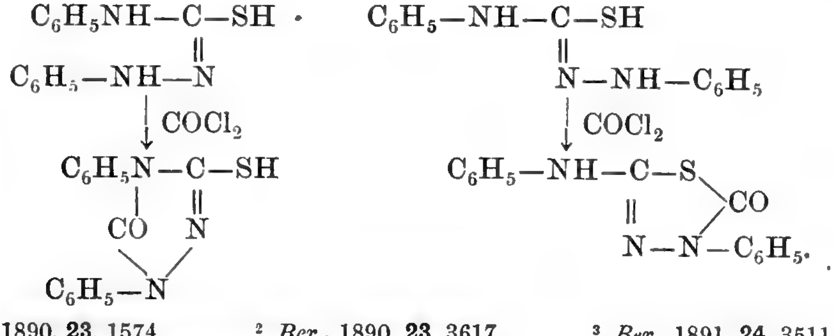
Hantzsch and Kraft [3] by the action of phenyl hydrazine on anisyl-phenyl-ketone on the one hand, and on its dichloride on the other, obtained two different anisyl-phenyl-ketone hydrazones which differed in appearance and solubility, and one of which was slowly transformed into the other in alcoholic solution.

The possibility of structural differences was finally excluded by Overton [4] by preparing two diphenyl-hydrazones of anisyl-phenyl-ketone, and of *p*-tolyl-phenyl-ketone by the method used by Hantzsch; several other hydrazones, however, could only be obtained in one form.

Anschütz and Pauly [5] prepared three isomeric diphenyl-hydrazones of dioxy-tartaric ester, two of which are readily transformed into the third by heating in solution or by traces of reagents such as iodine and sulphur dioxide: behaviour which is very characteristic of stereoisomerides; Bamberger and Schmidt [6] found that two hydrazones of benzoyl-formaldehyde could be obtained, and that these were interconvertible by means of solvents.

The only aldehyde hydrazones which have been obtained in different forms are the phenyl-hydrazones of protocatechuic aldehyde,[7] and of salicylic aldehyde,[8] and in both these cases the evidence is not sufficient to exclude the possibility of tautomerism in the benzene ring like that shown by phloroglucin.

The evidence of the existence of isomeric semicarbazones is insufficient; but Marckwald [9] has observed very definite isomerides of diphenyl thiosemicarbazine itself, which differ in melting point and in their reaction with carbonyl chloride. Their reactions are explained as follows:—



[1] *Ber.*, 1890, **23**, 1574. [2] *Ber.*, 1890, **23**, 3617. [3] *Ber.*, 1891, **24**, 3511.
[4] *Ber.*, 1893, **26**, 18; see also Hantzsch, *Ber.*, **26**, 1. [5] *Ber.*, 1895, **28**, 64.
[6] *Ber.*, 1901, **34**, 2001. [7] Wegscheider, *Monats.*, 1893, **14**, 386.
[8] Biltz, *Ber.*, 1894, **27**, 2288. [9] *Ber.*, 1892, **25**, 3098.

Both react with methyl iodide to give derivatives in which the methyl group appears to be attached to sulphur, which points to the absence of structural differences.

(*d*) *Stereoisomeric Aniles and other Compounds.*—Many unsuccessful attempts to prepare aniles, Schiff's bases, in isomeric forms were made before any indication of their existence was obtained.[1]

A new isomeride of ethylidene aniline was isolated by Eibner,[2] from the product of the reaction in water, which melted at 85·5° C., whereas that already known melted at 126° C. The two compounds are monomolecular, and the one with the lower melting point is readily converted into the other. Later, the same chemist with Peltzer[3] isolated two isomeric ethylidene *o*-toluidines, which were apparently structurally identical, and of which, again, the lower melting point form could be readily transformed into the higher. Hantzsch and Schwab[4] described two benzylidene *p*-toluidines in which the isomeride with the lower melting point is the more stable. The possibility of structural differences in simple aniles, like $C_6H_5-N=CH-CH_3$, need scarcely be considered, and the relations between the compounds exclude dimorphism, so that their existence must be due to stereoisomerism.

Lastly, Schall and Raschkowetzky[5] describe two isomeric carbodiphenylimides, $C\begin{smallmatrix} \diagup\!\!\!\diagup N-C_6H_5 \\ \diagdown\!\!\!\diagdown N-C_6H_5 \end{smallmatrix}$, between which there can be no structural difference.

(*e*) *Compounds of the type* $\begin{array}{c} a-N \\ \| \\ N-b, \end{array}$ *Azo and Diazo Compounds.*—Azo compounds ought to exist in isomerides similar to those of oximes and hydrazones, but that they do so has never been established in a satisfactory manner. Janowski[6] has described two trinitroazotoluenes and two *p*-azoxytoluenes; the evidence, however, is insufficient to allow any definite conclusion to be drawn from it.

The diazo compounds are well known to exist in isomeric forms, to explain which no hypothesis seems adequate except that of Hantzsch, together with the admission of structural isomerism. This subject is so involved, and moreover has so recently formed the subject of an exhaustive report,[7] that a mere mention must suffice. *Syn* and *anti*diazo compounds exist, which are represented thus

$$\begin{array}{r} C_6H_5-N \\ \| \\ X-N \end{array} \quad \text{and} \quad \begin{array}{l} C_6H_5-N \\ \quad\quad\;\; \| \\ \quad\quad\;\; N-X, \end{array}$$

where X represents an acidic radical, a hydroxyl group, or a metallic radical attached to oxygen. Diazonium compounds, which are structurally different from the diazo compounds, also exist.

The existing isomerides of compounds of the type $\begin{array}{c} a-C-b \\ \| \\ N-c \end{array}$ and allied types can only be satisfactorily explained with the aid of the Hantzsch-

[1] *Ber.*, 1891, **24**, 3518; **25**, 2020; *Ann. Chem. Phys.*, 1896, **9**, 433.
[2] *Ber.*, 1894, **27**, 1299.
[3] *Ber.*, 1900, **33**, 3460.
[4] *Ber.*, 1901, **34**, 822.
[5] *Ber.*, 1892, **25**, 2880.
[6] *Monats.*, 1888, **9**, 831; 1889, **10**, 583; *Ber.*, 1890, **23**, 1176.
[7] Morgan, *Brit. Assoc. Rep.*, 1902, **181**.

Werner hypothesis, which has predicted and accounted for all the cases of isomerism of this kind hitherto observed. The absence of isomerides in some cases in which they were expected—for instance, the oximes of aliphatic aldehydes and ketones—is not to be regarded as a serious objection, since one of the compounds may be so unstable as to be almost immediately transformed into the more stable isomeride, or again, in such cases as the azo compounds, either a suitable method for preparing the isomeride may not be known, or the compound may not be reactive enough to undergo transformation by any of the methods available.

II. Quinquevalent Nitrogen Compounds.

Attention was first drawn to the ammonium compounds with reference to the discussion whether valency was fixed or variable, and from 1816 onwards a lively controversy waged between chemists who maintained that ammonium chloride was a molecular compound, and those who held the view that it was an atomic compound in which nitrogen was quinquevalent.

Experiments made by V. Meyer and Lecco [1] showed that the union of trimethylamine with ethyl iodide on the one hand, and of ethyl-dimethylamine with methyl iodide on the other, gave rise to the same product; after an objection raised by Lossen [2] had been answered [3] this was regarded as strong evidence in favour of the atomic nature of these compounds. Had the results of these experiments been different an erroneous conclusion would have been arrived at. At present the doctrine of variable valency is accepted by most chemists, and ammonium chloride is usually represented as $\left.\begin{matrix}H\\H\\H\\H\end{matrix}\right\rangle N-Cl$ with a quinquevalent nitrogen atom attached to four atoms of hydrogen and one of chlorine.

(i) *The Formation of Substituted Ammonium Compounds.*

The rate of formation of substituted ammonium compounds from amines and alkyl halogen compounds varies to a very great extent, and is found to depend both on the alkyl groups in the amine and on that in the halogen compound. Much work has already been carried out on this subject, and much more will have to be done before one can hope to understand the reactions. Thus Menschutkin [4] investigated the velocity of the reaction between a very large number of alkyl halogen compounds and amines; no general conclusions can be drawn from this work, the amines being divided into three classes, according as the maximum rate of formation occurs (1) for the salt of the tertiary amine, (2) for the salt of the secondary amine, or (3) for the quaternary ammonium salt.

In all cases iodides reacted about seven times more rapidly than bromides, and these about a hundred times faster than chlorides.

It frequently happens that the same compound is formed quite rapidly in one way, and quite slowly or not at all in another way.[5]

[1] *Ber.*, 1874, **7**, 1747; **8**, 233, 936; *Annalen*, 1876, **180**, 170.
[2] *Ber.*, 1875, **8**, 49.
[3] *Ber.*, 1877, **10**, 309.
[4] *Zeit. phys. Chem.*, 1895, **17**, 191.
[5] Cf. also *Proc. Chem. Soc.*, 1901, **17**, 205.

Wedekind[1] compared the rate of formation of quaternary compounds from dimethylaniline and similar tertiary amines and various alkyl iodides. In all cases methyl, benzyl, and allyl iodides react much more rapidly than any others; the order of their rapidity, however, depends on the amine used.

This kind of effect is often attributed to 'stereochemical obstruction' or 'space filling,' in the same way as the phenomena observed in the esterification of diortho substituted benzoic acids by V. Meyer. There is certainly an effect of this sort. Thus, for example, tribenzylamine, $(C_7H_7)_3N$, is capable of reacting with methyl iodide; dibenzylaniline $(C_6H_5)(C_6H_5CH_2)N$ is not; and triphenylamine will not even react with hydrochloric acid. Again, the halides of normal alkyl groups invariably react more rapidly than those of the corresponding *iso* groups. All the facts cannot, however, be accounted for in this way. On such a view iodides should react less rapidly than chlorides. Also Menschutkin[2] finds that, whereas substitution of an alkyl group in the α position in pyridine, piperidine, or quinoline diminishes the velocity of reaction with alkyl bromides, the introduction of the same group in the β or γ position increases the velocity.

Much more work of a systematic kind is needed before any general conclusions on the subject can be drawn; all that we can at present say is that the rate of formation of an ammonium compound depends both on the alkyl radicals already present in the amine, and also on that which is to be added on to it.

(ii) *Compounds of the Type* Na_3bX.

The first experiments made on compounds having three radicals identical and one different were those of Meyer and Lecco already mentioned: a very large number of similar experiments have failed to produce isomerides of this type.

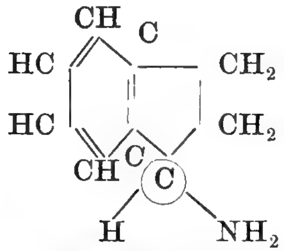
Le Bel[3] found that the chloroplatinate of benzyl-triethylammonium hydroxide was the same whether produced from triethylamine and benzyl chloride or from benzyl-diethylamine and ethyl iodide, and similarly with that of trimethyl-propyl ammonium hydroxide or tripropylmethyl- ammonium hydroxide, whereas that of trimethyl *iso*-butylammonium hydroxide was found to exist in two different crystalline modifications, the one being anisotropic needles which readily changed into octahedra; the chloride of the same base also exhibits differences of a similar kind. Similar differences were observed by Le Bel[4] in the chloroplatinate of dimethylamine, and by Arzruni and others[5] in ethylamine hydrochloride, tetramethyl ammonium chloride, m-xylidine hydrochloride, tropidine chloroplatinate, and several other similar salts. Although the evidence is insufficient to show that these differences are not due to isomerism, it is highly probable that they are merely due to dimorphism.

Messrs. Schryver and Collie[6] found that only one chloroplatinate of trimethyl-ethyl ammonium hydroxide, dimethyl diethyl ammonium hydroxide, and methyl-triethyl ammonium hydroxide could be prepared.

[1] *Stereochemie des fünf. Stickstoffes*, 1899, 18.
[2] *Jour. russ. phys. Chem. Ges.*, 1902, **34**, 411.
[3] *Compt. rend.*, 1890, **110**, 145; 1891, **112**, 725; *Bull. Soc. Chem.*, 1890 [3], **4**, 104.
[4] *Compt. rend.*, 1893, **116**, 513.
[5] Cf. Lehmann, *Molecular Physik*, vol. i. pp. 177, 539, 599; *Zeit. Kryst.*, vol. iii. p. 216.
[6] *Proc. Chem. Soc.*, 1891, vii. 39.

Professor Kipping observed a particularly interesting kind of isomerism among compounds of this type in which *b* and X both contain an asymmetric carbon atom.[1] This isomerism has now been very fully investigated in an admirable way by himself and his collaborators.[2]

Externally compensated (*d. l*) α-hydrindamine when treated with *d*-brom-camphorsulphonic acid, with the corresponding chlor acid,



or with *cis* π camphanic acid, was found to give rise to unequal quantities of two salts called the α and β salts, the β salt being that which is formed in smaller quantity. These salts differ in crystalline form, in amount of water of crystallisation, and often also in specific rotatory power ; these differences are not removed by recrystallisation from hot water, and both salts contain the inactive base.

It is unnecessary to discuss the large mass of detailed work which has been done in the painstaking demonstration that only one explanation of this isomerism is possible :[3] a brief summary of the conclusions will suffice.

It has been clearly shown that each of the two active hydrindamines, on combining with one of the above-mentioned acids, gives rise to two salts called αd and βd and αl and βl respectively, and that the original α salt obtained from the *d-l* base is a mixture of αd and αl in the form of a *partially racemic compound*, whereas the original β salt consists of a mixture of the two β salts or even of all four salts ; in this case it is called a *partially diracemic compound.*

In some cases there is a striking similarity between the αd and βd or the αl and βl salts respectively, which may be isodimorphous and not completely separable by crystallisation. The molecular rotatory powers of the β series of salts in aqueous solution are frequently abnormal, which may be due to incomplete electrolytic dissociation or to activity of the nitrogen atom (see page 190).

Evidence of a similar kind as to the existence of isomerides has been obtained for the brom-camphorsulphonates of benzylhydrindamine,[4] methylhydrindamine,[5] and *l*-menthylamine,[6] and for the chlor-camphorsulphonate of *d* and *l* methylhydrindamines,[7] although in these cases it seems impracticable to isolate the salts free from their isomerides.

The mandelates, tartrates, camphor-π sulphonates, and camphor-α sulphonates (Reychler) of these bases do not exhibit the same phenomena : these salts appear to be homogeneous. This isomerism, though extremely important from a theoretical point of view, appears not to be of general occurrence.

[1] *Trans. Chem. Soc.*, 1900, **77**, 861.
[2] *Trans. Chem. Soc.*, 1903, **83**, 873, 889, 902.
[3] *Trans. Chem. Soc.*, 1903, **83**, 937, 1147.
[4] *Trans. Chem. Soc.*, 1901, **79**, 430.
[5] 1903, **83**, 918.
[6] 1904, **85**, 65.
[7] Tattersall, 1904, **85**, 169

(iii) *Compounds of the type* Na_2bc X.

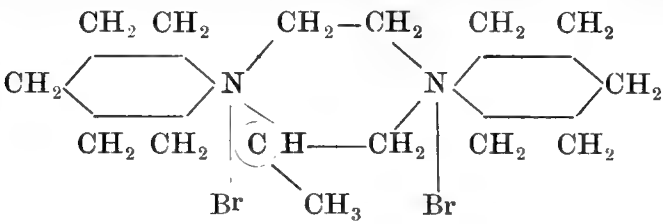
Messrs. Schryver and Collie[1] prepared the chloroplatinate of methyl-diethyl-isoamylammonium hydroxide from the iodides formed in the three possible ways, and found that when the processes were carried out in the cold, two crystalline modifications were obtained, an oblique and a prismatic, the former of which was unstable and readily passed into the latter. This difference might easily be due to dimorphism, as in the case of the compounds of the type Na_3b X.

The writer[2] investigated the formation in two different ways of a number of compounds with two identical radicals, and found that even when the reaction was carried out in the cold, the products obtained were in all cases the same. In a few instances the crude compounds differed to a slight extent, and one might even be gummy while the other was deposited in a crystalline state; these differences always disappeared when the substances separated from solutions. The *d*-camphor sulphonates prepared from both products were the same.

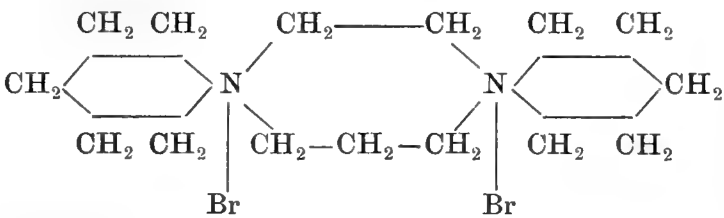
All attempts to get isomeric piperidinium salts have also been unsuccessful. Thus Menschutkin[3] found that ethyl-allyl-piperidinium iodide produced in the two possible ways was the same and so also was the chloroplatinate. Miss de Brereton Evans[4] obtained only one form of ethyl-propyl-piperidinium iodide, the crystals of which, however, showed enantiomorphism, and Wedekind[5] obtained only one form of benzyl-piperidinium iodide, methyl- and ethyl-acetates, and the corresponding bromides

Aschan[6] has investigated dipiperidinium derivatives, and though he obtained only one form of N.N. ethylene dipiperidinium dimethyl diiodide and the corresponding dibenzyl dichloride, found that two isomerides of ethylene-propylene dipiperidinium dibromide and of ethylene-trimethylene dipiperidinium dibromide and diiodide[7] seem to exist.

The first of these compounds contains an asymmetric carbon atom:



whereas the others do not:



[1] *Proc. Chem. Soc.*, 1891, vii. 39.
[2] *Proc. Camb. Phil. Soc.*, 1901, **11**, 111; *Trans. Chem. Soc.*, 1903, **83**, 1400.
[3] *Zeit. phys. Chem.*, 1895, **17**, 228; *Ber.*, 1895, **28**, 404.
[4] *Trans. Chem. Soc.*, 1897, **71**, 522.
[5] *Stereochemie*, 58.
[6] *Ber.*, 1899, **32**, 988; *Zeit. phys. Chem.*, 1903, **46**, 304.
[7] *Loc. cit.*, 306.

So far only a brief statement concerning these compounds has been made, and no full description of their properties or crystalline form has been given. The isomeric bromides differ in solubility in dilute alcohol (5·4 and 8·2); the iodides in solubility in water and also in their temperature of decomposition.

With the exception of these compounds described by Aschan, which, as will be seen later, must show isomerism, whatever view of their configuration and mode of formation be adopted, no compounds of the type under discussion have been shown to exist in isomeric forms, and it may therefore be concluded that under normal conditions stable isomerides cannot exist, the limit of 'space-filling' having been very nearly reached in some of the compounds used by the writer.

(iv) *Compounds of the type* N *a b c d* X.

No systematic efforts had been made to obtain isomerides of compounds of the above type before Wedekind's experiments were undertaken. Wedekind argued, from the experiments of Messrs. Schryver and Collie and others, that the groups in ammonium compounds were mobile, and that therefore isomerism could only exist when heavy groups were used and when the limit of 'space-filling' had nearly been reached.

The formation of phenyl-ethyl-methyl-allyl ammonium iodide in the three possible ways,[1] namely (*a*) combination of methyl-ethyl aniline and allyl iodide, (*b*) allyl-ethyl aniline and methyl iodide, and (*c*) allyl-methyl aniline and ethyl iodide, showed that only one product was obtained, though in the first case the compound was at once deposited in a crystalline state; whereas the other two combinations gave an amorphous product which readily became crystalline on rubbing or on separating it from solution. Similar phenomena were observed by the writer in the formation of phenyl-benzyl-ethyl-methyl ammonium iodide.[2] The union of benzyl iodide with ethyl-methyl aniline took place very readily and yielded a gummy solid which, on separating from solution, became crystalline and identical with that obtained by the addition of methyl iodide, or of ethyl iodide to the corresponding tertiary amines, which was crystalline from the first.

The phenomena observed by Wedekind in the phenyl-benzyl-allyl-methyl ammonium salts[3] are, however, of quite a different kind. This compound was prepared by the union of (*a*) allyl iodide and methyl-benzyl aniline, (*b*) methyl iodide and benzyl-allyl aniline, and (*c*) benzyl iodide and methyl-allyl aniline. Combinations (*a*) and (*c*) take place readily and give rise to the same product, the α compound, which crystallises in the prismatic system, melts at 140–142° C., and distils partly unchanged under reduced pressure. Combination (*b*) takes place very slowly and gives an oily product which is induced to crystallise only with great difficulty and yields a very small quantity of a crystalline solid, the β compound. This compound crystallises in a different form (also of the prismatic system), melts at 158–159° C., and distils unchanged under reduced pressure without melting. The α and β compounds could not be transformed one into the other.

Isomeric α and β chlorides and bromides were also prepared, which

[1] *Stereochemie*, 53; *Ber.*, 1903, **36**, 3791.
[2] *Trans. Chem. Soc.*, 1904, **85**, 224.
[3] *Stereochemie*, 33–52; *Ber.*, 1899, **32**, 517, 3561

differed in a similar way to the α and β iodides. Hantzsch and Horn[1] prepared the α and β iodides and made experiments to exclude the possibility of structural differences. Both iodides react as unsaturated bodies toward alkaline permanganate, and on oxidation give formic acid, which facts show that both are allyl compounds.

The writer has compared the properties of the β compound with those of phenyl-methyl-benzyl-propyl and *iso*propyl ammonium iodides, and found that it differs from both in melting-point and crystalline form, though in the latter particular it has a slight resemblance to the *iso*propyl compound.

No other case of a similar kind has been found, though Wedekind was deceived by abnormal reactions into thinking that there were isomerides of some other compounds. Thus the addition of allyl bromide to benzyl *iso*butyl-N-methyl-acetate and of methyl-brom-acetate to benzyl-allyl-*iso*butylamine gave rise to different products, the latter of which was subsequently found to be a mixture.

Methyl-allyl-tetrahydroquinolinium iodide[2] prepared in two ways was the same, and so with ethyl-benzyl-*iso*tetrahydroquinolinium iodide.[3]

The tetrahydroquinolinium derivatives produced by the addition of methyl iodide and of methyl- and ethyl-iodo-acetates to the corresponding tertiary tetrahydroquinoline compounds and which were at first thought to be isomeric[4] were afterwards[5] found not to have the same composition. Methyl tetrahydroquinolinium N-methyl- and ethyl-acetate iodides were produced by the first method, but the second gave a mixture of these with kairolin hydriodide.

A similar tetrahydro*iso*quinoline compound was obtained in one form only.[6]

Wedekind has also studied the formation of compounds in which two asymmetric nitrogen atoms are present.[7] Ethylene dikairolinium di-iodide was prepared in two ways and found to be the same; ethylene ditetrahydroquinolinium di-ethyl-acetate di-iodide, however, appears to be different when prepared in the two possible ways; the specimen formed by the addition of iodo-acetic ester melts at 164–165° C., whereas that formed by the addition of ethylene di-iodide melts at 50° C., with elimination of one molecule of iodo-acetic ester. The analyses of these compounds are, however, insufficient to prove identity, and it is possible that one of them is a mixture.

Wedekind examined the stable compound to ascertain if it was homogeneous, and decided that it was. Hence, the analogy between asymmetric nitrogen and carbon does not seem to hold here—namely, that, when two asymmetric atoms are produced, all four possible compounds should also be produced and combine in pairs to give externally compensated compounds separable by crystallisation.

(v) *Optical Activity of Substituted Ammonium Compounds.*

It was expected from analogy with carbon compounds that quinquevalent nitrogen compounds, N *ab cd* X, would exist in optically active forms, and repeated attempts were made to prepare such compounds before definite success was attained.

Le Bel[8] submitted dilute aqueous solution of various salts of the type,

[1] *Ber.*, 1900, **35**, 883. [2] *Stereochemie*, 75; *loc. cit.*, 63. [3] *Ber.*, 1901, **34**, 3986 [4] *Stereochemie*, 66. [5] *Ber.*, 1902, **35**, 178. [6] *Ber.*, 1903, **36**, 1158. [7] *Ber.*, 1903, **36**, 1165, 3796.[8] [8] *Compt. rend.*, **112**, 724.

Na_2bcX, and also two of the type, $NabcdX$—namely, methyl-ethyl-propylamine hydrochloride, and methyl-ethyl-propyl-*iso*butyl ammonium chloride—to the action of *Penicillium glaucum*. In the last case only the solution acquired a small but fugitive rotatory power of 0·4°–0·5°; the absence of activity in the other case was attributed to mobility of groups.

This result has been contradicted by Marckwald and Droste-Huelsdoff,[1] but reaffirmed by Le Bel, with the addition of further details.[2]

Wedekind[3] made several unsuccessful attempts to resolve the α phenyl-benzyl-allyl-methyl ammonium iodide, which was successfully resolved by Messrs. Pope and Peachey[4] by crystallising the camphorsulphonate from non-hydroxylic solvents (acetone and ethyl acetate). The active compounds were then more fully investigated by Messrs. Pope and Harvey.[5] The *d*-camphorsulphonate of the *d*-base had the molecular rotatory power $[M]_D = 218°$ in dilute aqueous solution, the corresponding *l*-*l* salt had $[M]_D = -211°$ and the iodides had $[M]_D$ about $\pm 200°$ in chloroform.

The writer[6] also succeeded in resolving phenyl-benzyl-ethyl-methyl ammonium iodide in a similar way. The *d*-*d* and *l*-*l* camphorsulphonates had $[M] = \pm 71°$. The difference between the values of $[M]_D$ for the basic ions in these two cases, namely 160° (approximately), and 19·5° caused by the replacement of the allyl by the ethyl radical, is remarkable.

A number of other active compounds are now being examined by Miss M. B. Thomas and the writer with a view of investigating the effect of substitution on the rotatory power. In the series containing the radicals phenyl, benzyl and methyl with propyl, *iso*propyl, *iso*butyl, and *iso*amyl the rotatory power appears to increase with the molecular weight of the last-mentioned radical, and in the last case far exceeds that of the allyl compound.

That the resolution of ammonium compounds does not always take place so readily as in the first case examined is evident from the writer's experiments,[7] and the unsuccessful attempts of Wedekind[8] to resolve *p*-tolyl-benzyl-allyl-methyl ammonium *d*-camphorsulphonate, a salt very similar to that first resolved.

So far no cyclic ammonium compounds have been resolved, though both α and β substituted pyridinium and piperidinium derivatives, and tetrahydroquinolinium compounds should be capable of giving rise to optical activity.[9]

All attempts to obtain optically active compounds of the type Na_2bcX have also been unsuccessful. Thus the writer[10] examined a number of such compounds, Messrs. Kipping and Barrowcliff[11] examined some piperidinium compounds, and Aschan[12] tried to resolve the N-N ethylene-trimethylene dipiperidinium compounds, though not in an entirely satisfactory way, but in no case was there any indication of activity. It is probable that all such compounds are planisymmetric, and therefore incapable of giving rise to optical activity.

1 *Ber.*, 1899, **32**, 560.
2 *Compt. rend.*, **129**, 548.
3 *Stereochemie*, 82.
4 *Trans. Chem. Soc.*, 1899, **75**, 1127.
5 *Trans. Chem. Soc.*, 1901, **79**, 828.
6 *Trans. Chem. Soc.*, 1903, **83**, 1418; 1904, **85**, 223.
7 *Loc. cit.*, 1405.
8 *Zeit. phys. Chem.*, 1903, **45**, 235.
9 *Trans. Chem. Soc.*, 1903, **83**, 1415.
10 *Loc. cit.*, 1903, **83**, 1406. Cp. also Harvey, *Trans. Chem. Soc.*, 1904, **85**, 412.
11 *Loc. cit.*, 1903, **83**, 1141.
12 *Loc. cit.*

(vi) *Compounds containing Asymmetric Carbon and Nitrogen Atoms.*

The examination of these compounds was undertaken with a view of establishing another analogy between asymmetric carbon and nitrogen atoms, and it has been shown [1] that when an active tertiary amine (methyl *l*-amyl aniline) combines with an alkyl iodide (allyl or benzyl iodide), unequal quantities of the two possible compounds are produced as anticipated if the nitrogen behaved like a carbon atom.

The two compounds formed with benzyl iodide differ somewhat in their solubility, but not enough to make a complete separation by crystallisation feasible : this can be effected by means of the camphor-sulphonates. One of the iodides is dextro- and the other is lævo-rotatory ; a solution of either in chloroform in the cold or in alcohol on warming becomes converted into the other until a state of equilibrium is reached, the change from one isomeride to the other being effected by the splitting up of the salt into benzyl iodide and amine, which then recombine, as in the racemisation of active nitrogen compounds in chloroform solution.

(vii) *The Configuration of Quinquevalent Nitrogen Compounds.*

(*a*) *A fixed Configuration necessary.*—The foregoing results demand a stable configuration for the molecule of ammonium compounds, in which the nitrogen atom is quinquevalent, and is attached to five univalent atoms or groups.

Werner [2] still adheres to a modification of the old ‘molecular compound hypothesis’ to account for the ammonium compounds, and regards the existence of isomerism and optical activity as an objection to the view generally accepted. Dr. J. C. Cain [3] takes the same point of view, regards the stability of the ammonium compounds towards alkalies as a further objection, and proposes a new hypothesis in which ammonium chloride is represented as $H_3N{=}Cl{-}H$. Two of the numerous important objections to this view may be mentioned : first, there is not enough evidence to show that compounds with the structure usually assigned to ammonium salts would not be stable, and still less for concluding that tervalent halogen derivatives would be stable ; and, secondly, the formulæ proposed to account for the isomeric hydrindamine salts—namely, $a_3N{=}X{-}b$ and $a_2bN{=}X{-}a$—do not account for the mode of formation of these salts, and the formulæ proposed for active nitrogen compounds—namely, $bcdN{=}X{-}a$—and $acdN{=}X{-}b$—are not optical antimers, and could not by a single process be produced together in equal quantities.

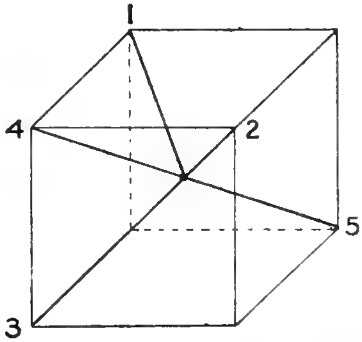
Five points cannot be arranged symmetrically around one point so as to be interequivalent ; hence either one or two of the valencies of nitrogen must be different from the others : this conclusion finds expression in all the configurations proposed, and is supported by the facts. It has been found impossible to prepare a quinquevalent nitrogen compound containing no electro-negative radical nor one containing more than two such radicals.[4]

(*b*) *The ‘Cubic Configuration.’*—The first configuration proposed was

[1] Jones, *Proc. Camb. Phil. Soc.*, 1904, xii. 466.
[2] *Annalen*, 1902, **322**, 261.
[3] *Memoirs of the Manchester Lit. and Phil. Soc.*, 1904, **48**, No. 14.
[4] Lachmann, *American Chem. Journ.*, 1896, **18**, 372.

the 'cubic' one suggested by van't Hoff in 1878,[1] in which the nitrogen atom is supposed to be at the centre of a cube and the five groups at five corners, thus :

FIG. 1.

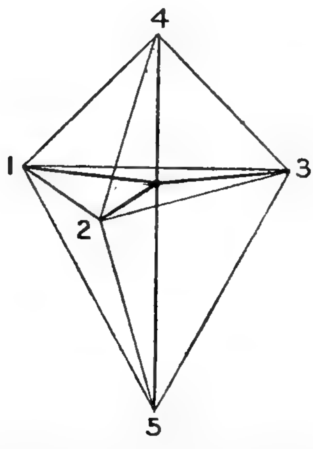


The disposition of the valencies would have to be altered to meet the requirements of recent experiments.

The number of isomerides required by this configuration is usually larger than by some of the others on account of the lower degree of symmetry which it possesses, and, since it has no special advantages, little use has been made of it.

(*c*) *The 'Double Tetrahedron' Configuration.*—The next configuration which was proposed is usually called the 'double tetrahedron' configuration and associated with the name of Willgerodt.[2] According to this view it is assumed that the two new groups are attached at right angles to the plane of the three already present, thus giving rise to an arrangement like a double tetrahedron. This arrangement has the highest degree of symmetry

FIG. 2.

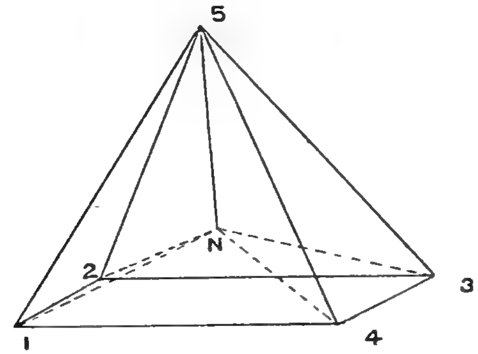


of any ; it requires the existence of (1) two isomerides of the type Na_3bX—namely, those in which a and b respectively occupy one apex while X occupies the other ; (2) three isomerides of the type Na_2bcX, one of which should exist in optical antimers ; and (3) four isomerides of the type $NabcdX$, all of which should exist in optically active forms.

[1] *Ansichten über Org. Chem.*, i. 80. [2] *Journ. prakt. Chem.*, 1890, **41**, 291.

(*d*) *The 'Pyramidal' Configuration.*—Behrend[1] discussed other possible arrangements of the five groups, and Bischoff[2] proposed the 'pyramidal' configuration in which the five groups are supposed to be situated at the angular points of a pyramid on a square base, the acidic radical occupying the apex thus :

FIG. 3.



Considering this arrangement as originally suggested we should expect (1) no isomerides of the type Na_3bX ; (2) two isomerides of the type Na_2bcX, one of which would be capable of existing in enantiomorphously related forms ; and (3) three isomerides of the type $NabcdX$, all of which should be capable of existing in optically active forms.

It is evident, however, that this view must be modified somewhat, for, since it does not represent the three groups in tervalent nitrogen compounds in one plane, there are three possibilities : (*a*) a change of valency direction occurs ; (*b*) the acidic radical does not occupy the apex (this assumption increases the number of possible isomerides very considerably) ; (*c*) an interchange of position between two groups occurs during the change of valency.

It is desirable to avoid the first assumption, if possible ; the last two have been made by Professor Kipping to account for the isomerism of the hydrindamine salts, and will be discussed in detail.

(*e*) *Only the Pyramidal Configuration accounts for the Facts.*—To decide between these various views we have the following facts which must be accounted for :

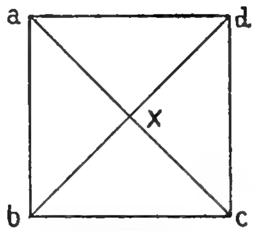
(1) The existence of stable, optically active compounds.
(2) The existence of the isomeric hydrindamine salts.
(3) The existence of isomerides of the type Na_2bcX only in the case recorded by Aschan, and the optical inactivity of all these compounds.

All the views account for (1), but the 'double tetrahedron' configuration does not account for (2), since both the new groups introduced during the change of valency are situated in the same plane symmetrically with reference to the existing groups, and are interchangeable by rotation.[3]

[1] *Ber.*, 1890, **23**, 454. [2] *Ber.*, 1890, **23**, 1972.
[3] See *Trans. Chem. Soc.*, **83**, 949.

This configuration may therefore be left out of consideration, and since the 'cubic' has no advantages and some disadvantages, we shall confine ourselves to the 'pyramidal,' which may conventionally be represented as a plane projection.

FIG. 4.

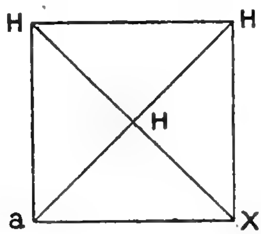


The way in which this configuration can be made to account for (2) and (3) has already been discussed.[1] The argument, therefore, need only be briefly stated.

In order to account for the existence of isomeric hydrindamine salts it is necessary to make one of two assumptions (*b*) or (*c*) (above) as to the manner in which the two new radicals, H and X, are attached to the amine, all three groups in the latter being in one plane with the nitrogen atom.

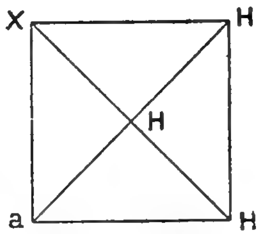
First H and X may be placed at the two unoccupied positions at the base of the pyramid, the asymmetric group (a) being also at the base (since if it occupy the apex no isomerism arises); the two salts would be thus represented:

FIG. 5.



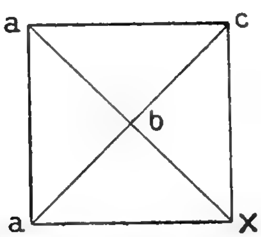
and

FIG. 6.



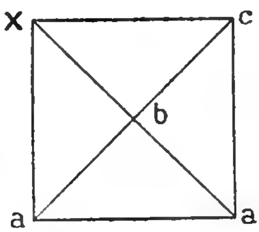
This assumption requires that the compound produced by the combination of *a*X and N *a b c* should have one of the configurations,

FIG. 7.



or

FIG. 8.

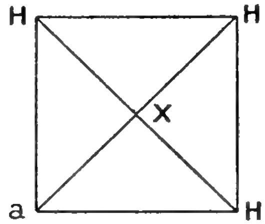


which are enantiomorphously related and should be optically active. This expectation cannot be experimentally realised.

[1] *Trans. Chem. Soc.*, **83**, 1404.

Secondly, it is assumed that, addition having taken place as before, the radical X then changes its position with the hydrogen atom at the apex of the pyramid, thus giving rise to a compound with the con-

FIG. 9.



figuration (fig. 9) which would be one of the isomerides, while the untransformed addition product would be the other (fig. 5 or 6).

On this view one isomeride (the untransformed product) is devoid of a plane of symmetry, whereas the other is planisymmetric, one should therefore have an activity due to the nitrogen atom, and this might account for the abnormal rotatory power of the salts of the β series.

This view will account (a) for the existence of one isomeride of Na_2bcX and its optical inactivity, since the original addition product (fig. 10) changes

FIG. 10.

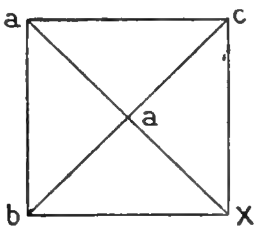
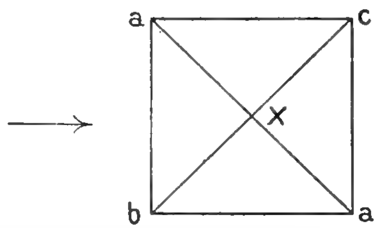


FIG. 11.



into a planisymmetric compound (fig. 11), and (b) for the inactivity of piperidinium compounds, which would be represented thus:

FIG. 12.

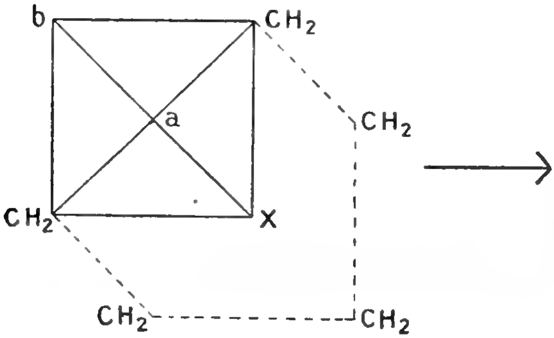
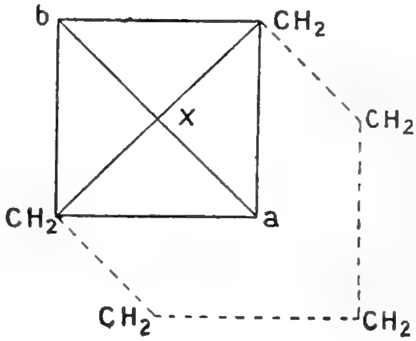


FIG. 13.

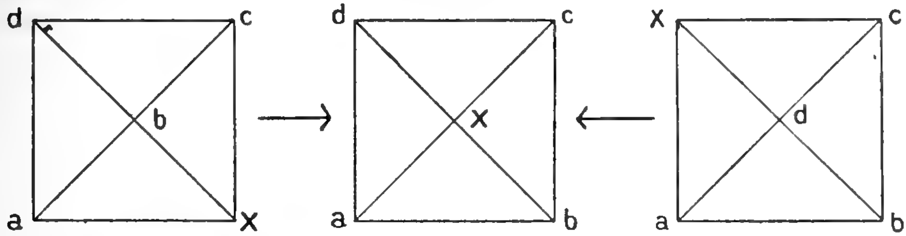


the plane of the piperidine ring being supposed perpendicular to the plane of the paper.

A difficulty arises with regard to compounds of the type, $NabcdX$, since they can be represented as giving rise to isomerides or not, according to the position which the new radicals are supposed to take up with reference to those already present.

Since, in general, no isomerism arises, the process probably takes place as follows :

FIG. 14.

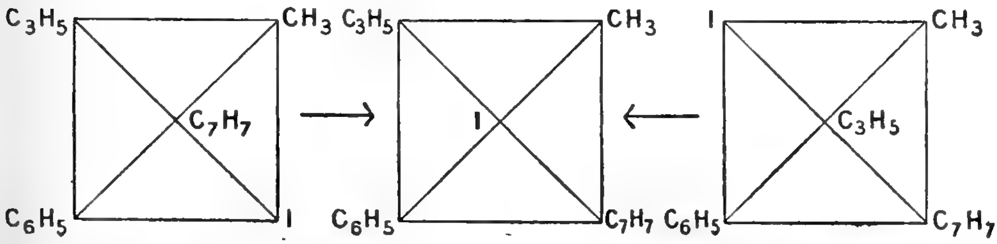


(abcN + dX) (adcN + bX)

giving rise to the same product.

But in one case at least—namely, that of the α and β phenyl-benzyl-allyl-methyl ammonium salts—different products are formed. It is true that the untransformed addition product might be expected to be an isomeride, as in the case of the hydrindamine salts, even in compounds of the type Na_3bX and Na_2bcX, and this may account for the labile amorphous products observed by Wedekind and the writer in some instances. Such instances are, however, of quite a different order to the stable isomerism of the α and β phenyl-benzyl-allyl-methyl ammonium salts ; our knowledge is unfortunately insufficient to enable us to form any idea of the reason for the unique position of those salts, and the following suggestion as to their mode of production is simply tentative. Since they are both stable it is better to regard these both as transformed products which might arise thus :

FIG. 15.

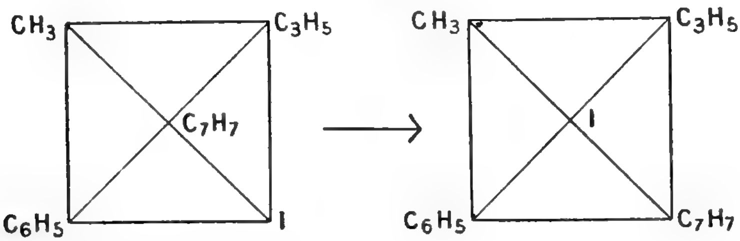


($C_6H_5.C_7H_7.CH_3.N + C_3H_5I$) ($C_6H_5.C_3H_5.CH_3N + C_7H_7I$)

The benzyl and allyl groups are regarded as the ones which inter change their positions with the iodine atom to form the α compound.

The β compound might arise thus :

FIG. 16.



($C_6H_5.C_7H_7.C_3H_5N + CH_3I$)

The benzyl radical is regarded as more mobile than the allyl, which is in accordance with observation. In all these cases the addition of the

alkyl and acidic radicals in both the possible positions gives rise to a mixture of optical antimers.

The isomerism observed by Wedekind in the diquinolinium compounds if established by further work is readily accounted for, since it would be expected that mobility would be diminished in these cases. Two externally compensated compounds ought to be produced, but since the product was apparently homogeneous, the two compounds must either be extremely similar or one of them must be formed in extremely small quantities, as in the case of the mannose cyanhydrins.

The existence and properties of the isomeric ethylene-trimethylene dipiperidinium dibromides discovered by Aschan are readily accounted for by any one of the proposed configurations, though Aschan himself says : [1] 'Das von van't Hoff mit dem gewohnten Scharfsinn dieses Gelehrten vorgeschlagene Modell für den pentavalenten Stickstoff ist die einzige mir bekannte, welche die Existenz und Inaktivität der beiden untersuchten Dipiperidid-Dibromide erklären kann.'

With the aid of the pyramidal configuration these isomerides would be represented thus:

FIG. 17.

Formed by the addition of trimethylene dibromide to ethylene dipiperidide:

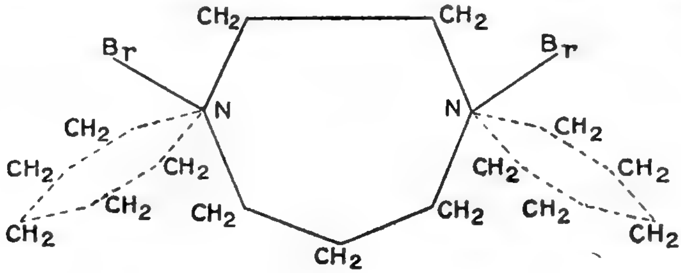
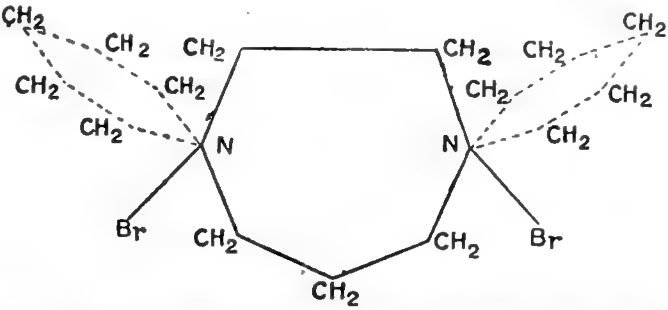


FIG. 18.

Formed by the addition of ethylene dibromide to trimethylene dipiperidide:



Interchange of positions between the bromine atom and one of the chains forming the central ring is not possible without almost complete disintegration of the molecule, and is improbable for other reasons, so that each bromine atom occupies a position at the base of the pyramid.

The planes of the piperidine rings are in each case represented as perpendicular to the plane of the paper ; each compound has thus a plane of symmetry in the plane of the paper and would be optically inactive.

Hence, the 'pyramidal' configuration of Bischoff, with the assumptions made as to the mode of formation of ammonium compounds from amines,

[1] *Loc. cit.*, 318.

is capable of accounting for all the observed phenomena. There are, however, a number of problems which still remain to be solved, notably, the investigation of the conditions which determine the stability of isomeric compounds such as the hydrindamine salts.

NOTE.—Since the above was written Wedekind and Oberheide have studied the question of isomerism in the paratoluidine series.[1] *p*-tolyl-methyl-ethyl-allyl ammonium iodide was produced in two ways, and *p*-tolyl-methyl-allyl-benzyl ammonium iodide was produced in three ways. In this case the stable isomerism observed in the corresponding phenyl compounds does not arise, and renders this still more difficult to understand. These compounds, too, have resisted all attempts to resolve them into their active constituents.

Dynamic Isomerism. *By* T. M. LOWRY, *D.Sc.*

[Ordered by the General Committee to be printed *in extenso.*]

I. *Introductory and Historical.*

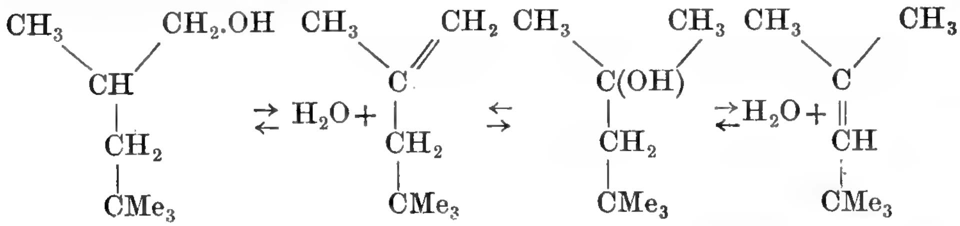
Berzelius.—Almost simultaneously with the discovery of isomerism the fact was recognised that isomeric compounds were sometimes capable of being converted into one another: in fact Berzelius, who in 1831 had introduced the term *isomeric* to express the relationship between tartaric and racemic acids, found it necessary in the following year to introduce the term *metameric* in order to distinguish those isomerides which differed in type and were on that account easily convertible into one another.[2] Berzelius' conception of metameric compounds is very similar to that which forms the subject of the present report, which deals with the phenomena of *dynamic isomerism* or *equilibrium between isomers.*

Liebig and Wöhler.—Of the two examples quoted by Berzelius, one (the isomerism of stannous sulphate, $SnSO_4$, and basic stannic sulphite, $SnOSO_3$) has not been realised, and the other (the supposed isomerism of cyanic and cyanuric acids) has proved to be an example of reversible *polymeric* change. The conversion of ammonium cyanate into urea, discovered by Liebig and Wöhler in 1828, is the earliest example of the type pictured by Berzelius. It is of interest to note that the first organic synthesis was effected with the aid of the first isomeric change.

Butlerow.—Little progress was made in the study of dynamic isomerism until the doctrine of valency rendered possible the modern development of structural chemistry. In the modern period the first and most important contribution to the theory of dynamic isomerism is to be

[1] *Ber.*, 1904, **37**, 2712.
[2] Full quotations are given in Professor Armstrong's article on 'Isomerism,' Morley and Muir's edition of Watts' *Dictionary of Chemistry.*

found in Butlerow's paper 'Ueber Isodibutylen,'[1] a paper which is remarkable in that it anticipated by a quarter of a century the views that are generally held at the present day. Butlerow's experiments showed that in presence of sulphuric acid equilibrium is established between the two olefines and the two isomeric alcohols formulated below, so that on oxidising with chromic acid products were obtained characteristic of each of these four substances :—



In no previous case had the existence of a *reversible isomeric change* been demonstrated, and Butlerow fully realised the importance of his discovery. At the end of his paper he suggested that a similar equilibrium between isomers might exist even in the absence of any special catalytic agent and that this would account for the formation of isomeric ethers from prussic acid

$$\underset{\text{ethyl cyanide}}{C_2H_5.C:N} \leftarrow \underbrace{H.C:N \rightleftarrows HN:C:}_{\text{prussic acid}} \rightarrow \underset{\text{ethyl } isocyanide}{C_2H_5.N:C:}$$

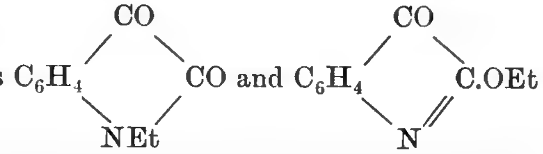
and for a number of other abnormal changes.

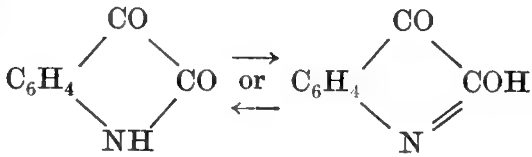
Subsequent investigations have fully demonstrated the correctness of Butlerow's theory since reversible isomeric changes have been found to be of frequent occurrence, especially amongst the ketones and nitro-compounds.

Isomeric change not spontaneous.—The only important modification of Butlerow's theory that has taken place depends on the proof that has recently been given[2] that even the most easily convertible compounds do not change spontaneously but that in all cases a catalytic agent is necessary for the establishment of equilibrium. The necessity for a third substance in order to bring about chemical change has been persistently advocated by Armstrong and has been demonstrated experimentally by Dixon, Baker and others in the combustion of carbon monoxide and phosphorus, and in the union of hydrogen with oxygen and with chlorine. Baker has further demonstrated the remarkable fact that moisture is necessary not only for the (apparently direct) union of ammonia and hydrogen chloride, but also for the dissociation of ammonium chloride, which cannot be decomposed by heat alone. Recent observations have extended the proof to the reversible isomeric change of nitro-camphor and β-bromonitrocamphor and it has been found that even the transference of a mobile hydrogen atom cannot take place within the molecule, but is dependent on the formation of a complex molecular circuit. It is therefore impossible to maintain any longer a distinction between those isomerides which are only convertible in presence of a specially added catalytic agent and those which find in the ordinary dirt of the laboratory the catalytic agent that they need and which therefore appear to change spontaneously.

[1] *Ann.* 1877, **189**, 44.

[2] Lowry, *Trans.* 1899, **75**, 219.

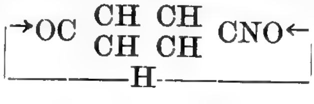
Abnormal Chemical Changes explained by Butlerow's Theory.—Simultaneously with the development of the theory of dynamic isomerism a large number of observations were being made which have only found a satisfactory explanation in the fully developed theory. The formation of two series of ethers from prussic acid was explained by Butlerow in 1877. Baeyer in 1883 was able in a similar manner to account for the existence of isomeric ethers  of isatin by supposing that one of them was derived from a labile *pseudo*-isatin which was converted into ordinary isatin whenever attempts were made to prepare it :—



In the same way it is easy to account for the apparent identity of nitrosophenol and quinoneoxime by supposing that one of these compounds undergoes isomeric change in the course of preparation :

$$ON.C_6H_4.OH \underset{\longleftarrow}{\overset{\longrightarrow}{\text{or}}} HO.N : C_6H_4 : O.$$

Laar's Theory.—In his paper, 'Ueber die Möglichkeit mehrerer Strukturformeln für dasselbe chemische Verbindung,' Laar, in 1885, rendered an important service by calling attention to the existence of a large number of facts of this kind. Unfortunately he rejected the explanation given above and put forward in its place his theory of *tautomerism.* According to this theory the product obtained by the action of nitrous acid on phenol, or of hydroxylamine on quinone, has actually not one but both of the alternative constitutions formulated above, the hydrogen atom oscillating between the two positions indicated in the formula



in a manner comparable with the vibrations that give rise to light. The incorrectness of Laar's theory was proved when, in 1895 and the years immediately following, it was found that the isomeric forms of several ketones and nitro- compounds could be isolated in the solid state and were only slowly converted into one another. The necessity for a catalytic agent has also shown that the oscillation of the hydrogen atom is not an intramolecular process but, like other chemical changes, can only take place within a complex molecular circuit. The distinction between the two theories is of importance at the present time, because it is not inconceivable that tautomerism may actually exist as an intramolecular phenomenon, though all the cases to which the term has hitherto been applied appear to be examples of dynamic isomerism.

Physical Phenomena explained by Butlerow's Theory.—In addition to affording an explanation of many puzzling chemical changes the theory of dynamic isomerism has proved exceptionally fertile when applied to physical phenomena. Thus the gradual change of rotatory power which takes place in freshly prepared solutions of many of the sugars was observed as long ago as 1846 but has only recently been shown to be due to the establishment of equilibrium between isomeric forms of the sugar. The formation of violet salts from colourless violuric acid, of red and yellow salts from colourless *p*-nitrophenol and of highly dextro-rotatory salts from lævo-rotatory nitrocamphor are due to similar changes or structure. Again there is good reason to suppose that many of the phenomena of luminosity are dependent on reversible isomeric change or on the analogous reversible changes involved in association and dissociation. This is almost certainly true of the fluorescence and phosphorescence or organic compounds and there is reason to think that the flash of light emitted when crystals of sugar or saccharin are crushed is also a manifestation of isomeric change.[1]

The bearing of Dynamic Isomerism on Chemical and Physiological Changes.—The mere presence of the mechanism necessary for dynamic isomerism appears to facilitate chemical change and in many cases it is probably an essential factor. Thus Lapworth has recently shown [2] that the bromination of acetone is dependent on the presence of a minute amount of the enolic form, the ketone itself being apparently unacted on by the halogen. A similar explanation may be given of the great activity of phenol and aniline as compared with benzene and of the inhibiting influence of ortho- substitution. In this connection it is of interest to note that the most important natural organic materials, such as the sugars and the albuminoids, are very rich in those plastic groups which most frequently give rise to dynamic isomerism and to this fact their great activity may at least in part be attributed.

II. *The Nature of Dynamic Isomerism.*

1. *Definition.*—Under the heading of dynamic isomerism are included all those cases in which it is possible to establish a condition of *equilibrium between isomers.* It may also be defined as a condition of *reversible isomeric change.*[3] But if this definition is used it must be remembered that reversal is largely a matter of conditions and that all isomeric changes are probably accompanied by a certain amount of back-action, even though this may be too small to be detected by the methods commonly used.

2. *Equilibrium between Isomers is only possible in presence of a third substance.*—Proof of this was first obtained in the case of nitrocamphor,[4] solutions of which in chloroform could sometimes be kept for two or three weeks without undergoing change, although usually sufficient impurity was present in the solution to bring about equilibrium between the normal and pseudo forms in the course of a single week.

$$[82\ \%]\ C_{10}H_{14}\Big\langle\begin{array}{l}CH.NO_2\\ \ |\\ CO\end{array} \quad \rightleftarrows \quad C_{10}H_{14}\Big\langle\begin{array}{l}C:NO_2H\\ \ |\\ CO\end{array}\ [18\ \%]$$

Normal nitrocamphor — *Pseudo*-nitrocamphor

[1] Armstrong and Lowry, *Proc. Roy. Soc.* 1903, **72**, 258.

[2] *Trans. Chem. Soc.* 1904, **85**, 30.

[3] Lowry, *Trans.* 1899, **75**, 235.

[4] Lowry, *ibid.* p. 220.

Similar observations have been made by Forster,[1] who found that a solution in chloroform of enolic α-benzoylcamphor could be 'preserved in darkness during twelve hours, exposed to bright sunlight during two hours and even sown with a crystal of the ketonic isomeride' without undergoing change; usually, however, six days were sufficient to bring about the condition of equilibrium indicated in the equation

$$[39\,\%]\; C_{10}H_{14}\left\langle\begin{array}{l} CH.CO.C_6H_5 \\ \,| \\ CO \end{array}\right. \rightleftarrows C_{10}H_{14}\left\langle\begin{array}{l} C.CO.C_6H_5 \\ \,\| \\ C.OH \end{array}\right. \;[61\,\%].$$

More recently it has been found possible to prepare solutions in benzene containing a *mixture* of normal and pseudo β-bromonitrocamphor which could be kept unchanged during several days in a graduated flask, but reached a condition of equilibrium in a single day when brought into contact with the softer glass of a polarimeter tube.[2] Of themselves, therefore, these isomerides are as stable as, for instance, are ethyl alcohol, $CH_3.CH_2.OH$, and methyl ether, $CH_3.O.CH_3$, or methyl acetate, $CH_3.CO.O.CH_3$, and propionic acid, $CH_3.CH_2.CO.OH$, but unlike these latter substances they *become isodynamic* in presence of an almost inconceivably minute amount of impurity. The addition to a solution of nitrocamphor in benzene of 0·0001 per cent. of piperidine is sufficient to establish equilibrium in two or three hours.

3. *An Ionising Solvent may promote Isomeric Change.*—Although in the cases described neither benzene nor chloroform is capable of bringing about isomeric change, it is possible that an ionising solvent may act as the necessary 'third substance.' The isomeric change of nitrocamphor is accelerated to some extent by acids as well as by alkalies, and in ionising solvents the change is very rapid even when purified material is used; as pseudo-nitrocamphor is itself a strong acid it may well act under these conditions as a catalytic agent. In the case of aqueous solutions of glucose quantitative measurements have shown that the isomeric change cannot be ascribed to acid or to basic impurities, whilst neutral salts retard rather than accelerate the change; the effect appears, therefore, to be produced directly by the solvent, assisted, perhaps, by the feebly acid properties of the glucose itself.[3]

4. *Many substances only become Isodynamic at High Temperatures or in presence of a special Catalytic Agent.*—Whilst it is now recognised that the changes which Butlerow regarded as spontaneous are actually brought about by a trace of acid or alkaline impurity or by an ionising solvent, there are many substances which, like the isodibutylenes, only become isodynamic under somewhat special conditions. Thus many sulphonic acids, like Butlerow's olefines, become isodynamic when dissolved in concentrated sulphuric acid; again where isomeric change involves the transference of an alkyl group, it may often happen that an alkyl iodide or an aluminium haloid is the only efficient agent. Apart from their great scientific and commercial importance these cases of dynamic isomerism are of interest as enabling isomerides to be directly balanced against one another of which the relative stability could otherwise be determined only indirectly from the heats of combustion. In other cases a reversible isomeric change appears to set in spontaneously when the temperature is

[1] *Trans.* 1901, **79**, 999. [2] Lowry, *Proc.* 1903, **19**, 131.
[3] Lowry, *Trans.* 1903, **83**, 1314.

raised. A high temperature can scarcely do more than increase the activity of the impurities present in the material but these may easily be introduced at high temperature owing to incipient decomposition or to action on the walls of the containing vessel.

5. *Equilibrium is determined by the Velocities of Isomeric Change in opposite directions.*—The proportions of the isomerides in the ultimate mixture is determined by the ratio of the velocities with which they undergo isomeric change under the given conditions. If these velocities are equal there will be 50 per cent. of each isomeride, but if one undergoes change ninety-nine times as fast as the other, there will only be 1 per cent. of it in the mixture. 'Complete' isomeric changes are merely limiting cases in which one velocity is small compared to the other, and as it is difficult to detect a back action in which the ratio of the velocities is greater than 100 to 1, the distinction between complete and incomplete changes is of very small importance. It may be added that solids are usually incapable of undergoing isomeric change but if such a change should occur (owing, for instance, to incipient fusion or to the presence of a trace of solvent), it is usually complete, back action being possible only in the liquid or gaseous state. Thus Walker and Hambly [1] have shown that the conversion of ammonium cyanate into urea, which is complete when the solution is evaporated to dryness, is reversible in solution. In a normal solution at 59·6°, 14·4 per cent. of ammonium cyanate undergoes isomeric change in a minute, and 0·0038 per cent. of urea. Equilibrium is reached when there is 5 per cent. of cyanate and 95 per cent. of urea, as indicated by the equation

$$[5\ \%]\ NH4.O.C\ \ N \rightleftarrows CO(NH_2)_2\ [95\ \%].$$

The concentration of the ammonium cyanate is then only N/20, and its velocity of change is reduced to half that in normal solution. Equilibrium is reached when the ratio 95/5 of the concentrations is equal to the ratio 7·2/0·0038 of the velocities of change in opposite directions.[2]

Ammonium cyanate changes slowly in aqueous solutions at ordinary temperatures; at 100° equilibrium is reached almost immediately. Ammonium thiocyanate, on the other hand, does not change in aqueous solution, but in the fused state at 170° it changes at about the same rate as ammonium cyanate in aqueous solution at 60°.[3] The predominance of the thiocyanate in the equilibrium

$$[75{\cdot}7\ \%]\ NH_4.S.C : N \rightleftarrows CS(NH_2)_2\ [24{\cdot}3\ \%]$$

is in marked contrast to the instability of the cyanate.

6. *Isomeric Change proceeds according to a simple Logarithmic Law, and the Period of Change is the same for different Isomerides.*—The logarithmic law has been verified in the case of glucose and other sugars,[4] in the case of π-bromonitrocamphor [5] and in many other instances. If, however, one of the isomerides is an active catalyst, or if by reason of association or dissociation only part of the material is in a condition to undergo isomeric change, the velocity-constant may vary as the concentration changes. In the absence of such disturbances the period of change must be the same

[1] *Trans.* 1895, **67**, 746.

[2] For observations on the alkyl thiocyanates see Walker and Appleyard, *Trans.* 1896, **69**, 193

[3] Reynolds and Werner, *Trans.* 1903, **83**, 1.

[4] Osalca, *Zeit. phys. Chem.* 1900 **35**, 661.

[5] Lowry, *Trans.* 1899, **75**, 227.

for the different isomerides, though large accidental discrepancies may occur when isomeric change depends on a small amount of a third substance. A fair agreement between the two periods was observed in solutions in benzene of normal and pseudo π-bromonitrocamphor [1] but Forster's curves for the two α-benzoylcamphors show a period twice as great for the ketonic as for the enolic form.

7. *Catalytic Agents alter the velocity of Isomeric Change but do not disturb the Equilibrium.*—Schiff [2] supposed that in the case of ethyl aceto-acetate

$$CH_3.CO.CH_2.CO.OEt \rightleftarrows CH_3.C(OH) : CH.CO.OEt$$

the material was converted by a trace of sodium ethoxide wholly into the enolic, and by a trace of piperidine wholly into the ketonic, form. This is impossible on theoretical grounds and has been disproved experimentally in this and in other cases.[3] It therefore follows that *catalytic agents accelerate both isomeric changes in the same ratio.*

8. *The Equilibrium may be affected by the Solvent, Concentration and Temperature.*—The direct effect of these is probably small, but if there is a tendency for one or both of the isomerides to polymerise, as in the case of the nitroso- and many hydroxylic compounds, or to combine with the solvent, as in the case of normal nitrocamphor dissolved in benzene, or to combine with one another, as in the case of thiourea and ammonium thiocyanate [4] or to become ionised, as in aqueous solutions of the cyanates and pseudonitro- compounds, very marked effects may be indirectly produced. Thus Wislicenus has shown [5] that associating solvents and high concentrations favour the formation of the (dimolecular) enolic form of ethylic phenylformylacetate

$$CHO.CHPh.CO_2Et \rightleftarrows HO.CH : CPh.CO_2Et.$$

In the contrary direction, Perkin has shown [6] that high temperatures increase the proportion of the ketonic form of the diketones, probably by dissociating the dimolecular enolic forms.

The great increase in stability of ammonium cyanate in dilute aqueous solution may be attributed to the large proportion of the salt which is then in an ionised condition and only indirectly available for isomeric change—

$$CO(NH_2)_2 \rightleftarrows NH_4.O.CN \rightleftarrows \overset{+}{N}H_4 \mid \overline{O}CN.$$

Thus Walker and Hambly [7] have obtained evidence that at the dilution of N/2000 ammonium cyanate and urea would be equally stable, and would be present in equal proportions in the mixture. On somewhat similar lines Hantzsch and Kinchenberger have contended [8] that nitroform in anhydrous solvents exists almost exclusively in the normal modification, but that in aqueous solutions it is mainly in the ionised pseudo- modification, *pseudo*-nitroform being one of the strongest known acids :

$$CH(NO_2)_3 \rightleftarrows (NO_2)_2CH : NO_2H \rightleftarrows (NO_2)CH : \overline{N}O_2 \mid \overset{+}{H}.$$

[1] *Loc. cit.*

[2] *Ber.* 1898, **31**, 601.

[3] See Schaum, *Ber.* 1898, **31**, 1964; and Lowry, *Trans.* 1899, **75**, 223.

[4] Reynolds and Werner, *loc. cit.*

[5] *Ann.* 1896, **291**, 182.

[6] *Trans.* 1892, **61**, 801.

[7] *Loc. cit.*

[8] *Ber.* 1899, **32**, 628.

9. *The Ultimate Product of Isomeric Change is a Mixture.*—It is necessary to emphasise the fact that except when isomeric change is complete the ultimate product is not a definite compound or a new isomeride but merely a mixture. Thus if the ultimate product of the isomeric change of glucose were a definite third isomeride, as has been suggested by Lippmann,[1] by Tanret[2] and more recently by Simon,[3] it would be impossible by mere crystallisation to reconvert it into the labile α-glucose. So also if ammonium thiocyanate and thiourea were converted *completely* into the compound $3AmCNS,CS(NH_2)_2$, postulated by Reynolds and Werner, it would be impossible by mere cooling to crystallise from the fused mass anything but the compound in question.

10. *The Classification of Dynamic Isomerides.*—Following Butlerow's example dynamic isomerides have usually been divided into two classes according as isomeric change takes place 'spontaneously' or only under special conditions. The 'spontaneous' changes have often been called 'tautomeric,' whilst the other group have been distinguished as 'ordinary' isomeric changes. Such a distinction may be convenient but cannot be defended on any other ground, for the spontaneity of the change is not an inherent property of the substance but depends on the presence or absence of a catalytic agent in the dirt that normally accompanies it. It must also be remembered that many isomeric changes which are not spontaneous at ordinary temperatures appear to become so when the temperature is raised, and the classification in question thus unconsciously involves an arbitrary temperature limit. But although no satisfactory classification of dynamic isomerides can be made on the basis of the readiness with which they undergo change, it is nevertheless possible to distinguish two principal groups, of which the second includes the majority of the so-called spontaneous changes.

These two groups are as follows:

A. *Isomeric changes in which two radicles are interchanged*, of which neither can be split off alone as an ion. Closely related to this group are a number of cases in which a double bond is shifted in an unsaturated compound.

B. *Isomeric changes in which a single radicle is transferred* which is capable in at least one of the isomerides of acting as an ion; the transference is accompanied by a rearrangement of bonds in the molecule.

The fact that changes of these two types usually take place under different conditions and in presence of different catalytic agents, goes far to show that the distinction is not arbitrary but fundamental. These two groups of changes are dealt with in the two following sections. Optical inversion, which includes examples from both groups, is discussed under a separate heading.

III. *Isomeric Changes in which Two Radicles are Interchanged.*

1. *Interchange of Radicles in Aliphatic Compounds.*—Butlerow's observation that the isodibutylenes are accompanied by isomeric alcohols is of importance not only as affording an illustration of this type of

[1] *Ber.* 1896, **29**, 203.
[2] *Bull. Soc. Chem.* 1896, iii. **15**, 195.
[3] *C. R.* 1901, **132**, 487.

dynamic isomerism but also because it proves that the interchange of H and OH depends on the separation of a molecule of water. Changes of this type frequently occur when alcohols are dissolved in sulphuric acid, as, for instance, in the production of tertiary butyl derivatives from isobutyl alcohol

$$HO.CH_2.CHMe_2 \rightleftarrows CH_2:CMe_2 + H_2O \rightleftarrows CH_3.CMe_2.OH.$$

In the conversion of pinacone into pinacoline the reversible separation of a molecule of water would account for the interchange of CH_3 and OH.

$$\begin{array}{l} CMe_2.OH \\ | \\ CMe_2.OH \end{array} \rightleftarrows H_2O + \left.\begin{array}{l} CH_3.CMe \\ \quad | \\ HO.CMe \end{array}\right\rangle CH_2 \rightleftarrows \begin{array}{l} CH_3.CMe_2 \\ \quad | \\ HO.CMe\ OH \end{array} \rightleftarrows H_2O + CMe_3.CO.CH_3.$$

A similar separation of HBr may be involved in the conversion, in presence of aluminium bromide, of propyl into isopropyl bromide

$$CH_3.CH_2.CH_2Br \rightleftarrows HBr + CH_3.CH:CH_2 \rightleftarrows CH_3.CHBr.CH_3$$

whilst in the conversion of α into γ-bromoacetoacetic ester the intermediate product would be a ring compound:

$$CH_3.CO.CHBr.CO_2Et \rightleftarrows HBr + \left.\begin{array}{l} CH_2 \\ | \\ CO \end{array}\right\rangle CH.CO_2Et \rightleftarrows CH_2Br.CO.CH_2.CO_2Et.$$

2. *Isomeric Change of Unsaturated Compounds.*—This is merely another phase of the preceding case, for the isomeric change depends on association with H_2O, H_2SO_4, or HBr, instead of on dissociation, and takes place under similar conditions. Thus the undecyclenes, like Butlerow's octylenes, are in equilibrium in presence of sulphuric acid, the proportions being indicated in the equation [1]

$$(4\%)\ CH_2:CH.CH_2.C_8H_{17} \rightleftarrows CH_3.CHOH.CH_2.C_8H_{17} \rightleftarrows CH_3.CH:CH.C_8H_{17}\ (96\%).$$

At high temperatures changes of this type take place readily in contact with platinum black or alumina, for instance,[2]

$$CH_2\left\langle\begin{array}{l} CH_2 \\ | \\ CH_2 \end{array}\right. \rightleftarrows CH_3.CH:CH_2;$$

under conditions such as these the conversion probably depends on association with water, the activity of a trace of moisture being greatly increased by the high temperature and the presence of the contact substance. Isomeric changes of this kind are very frequent, especially amongst the terpenes. They may lead either to the shifting of a double bond, as in the conversion of dihydrocarvone into carvenone

$$CH_3.CH\left\langle\begin{array}{l} CO.CH_2 \\ CH_2.CH_2 \end{array}\right\rangle CHMe:CH_2 \rightleftarrows CH_3.CH\left\langle\begin{array}{l} CO.CH \\ CH_2.CH_2 \end{array}\right\rangle\!\!\rangle C.CHMe_2$$

or to a rearrangement of the ring-system in the molecule, as when pinene

[1] Thoms and Mannich, *Ber.* 1903, **36**, 2544.

[2] Tanatar, *Zeit. phys. Chem.* 1902, **41**, 735; Ipatieff and Huhn, *Ber.* 1903, **36**, 2014.

is converted through its hydrochloride into camphene or camphor into carvenone.[1]

In the hexachlorocycloketopentenes, studied by Küster,[2] the shifting of the double bond is accompanied by the transference of a halogen atom, and equilibrium is established fairly rapidly at 210°, the necessary catalyst being probably HCl,

$$[\beta=61{\cdot}4\,\%]\ \left.\begin{array}{l} CCl:CCl \\ | \\ CCl_2.CCl_2 \end{array}\right\rangle CO \rightleftarrows \left.\begin{array}{l} CCl.CCl_2 \\ \| \\ CCl.CCl_2 \end{array}\right\rangle CO\ [\gamma=38{\cdot}6\,\%].$$

Included in this group are the *stereoisomeric changes* of unsaturated compounds. The conversion of maleic into fumaric acid, which takes place at ordinary temperatures in presence of HBr, is almost complete,

$$\begin{array}{c} H.C.CO_2H \\ \| \\ H.C.CO_2H \end{array} \rightleftarrows \begin{array}{c} CO_2H.C.H \\ \| \\ H.C.CO_2H \end{array}$$

but the dibromotolanes which are convertible at 210° are almost equally stable and are present in approximately equal quantities in the melt.[3]

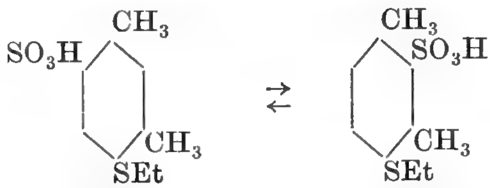
$$[48\,\%]\quad \begin{array}{c} C_6H_5.C.Br \\ \| \\ C_6H_5.C.Br \end{array} \rightleftarrows \begin{array}{c} C_6H_5.C.Br \\ \| \\ Br.C.C_6H_5 \end{array}\quad [52\,\%]$$

In each case isomeric change may be due to association with HBr, though another explanation is available in the case of maleic acid (compare p. 211).

Amongst nitrogen compounds similar equilibria are observed in the stereoisomeric oximes [4] and the *syn-* and *anti-*diazo- compounds.[5]

3. *Interchange of Radicles in Aromatic Compounds.*—One of the most characteristic properties of aromatic compounds is the ease with which they undergo isomeric change, so that almost any radicle that can be attached to the nitrogen of aniline or the oxygen of phenol can be subsequently interchanged with a hydrogen atom in the nucleus. In this way it is possible to transfer radicles as diverse as the halogens, NO_2, OH, SO_3H, COPh, NHPh (semidine), $PhNH_2$ (benzidine), and (under somewhat forced conditions) CH_3. The ring-substituted compounds are very stable, and the back action is usually slight, but as scarcely any attempt has yet been made to study these changes from the standpoint of equilibrium, it is impossible to say to what extent reversal occurs in any given case. Two ring-substituted compounds may exhibit a well-defined equilibrium, and such a case is found in the ethylxylenesulphide sulphonic acids,[6] the stable proportions in the mixture being indicated by the equation

[90–92 %]



[10–8 %].

[1] Bredt, *Annalen*, 1901, **314**, 369; compare Armstrong and Lowry, *Trans.* 1902, **81**, 1469, and p. 214 of this report.

[2] *Zeit. phys. Chem.* 1895, **18**, 161.

[3] Wislicenus, *Dekanatschrift*, Leipzig, 1890.

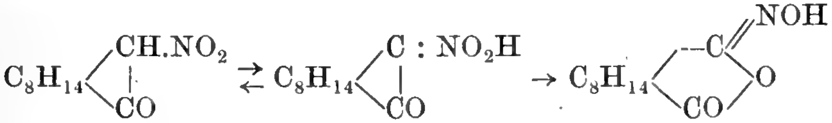
[4] Cameron, *J. phys. Chem.* 1898, **2**, 409; Carveth, *ibid.* 1899, **3**, 437.

[5] See Dr. Morgan's report, Belfast 1902, and Hantzsch, *Die Diazoverbindungen*, *Ahren's Sammlung*, 1902.

[6] Harker, *Thesis*, London, 1903.

The remarkable manner in which a small amount of *o*- acid persists in the mixture formed on sulphonating toluene affords similar evidence that this acid has a definite place in the equilibrium.

4. *The Beckmann Change.*—These interactions, in which an alkyl group attached to carbon is interchanged with a negative radicle attached to nitrogen, belong essentially to the group of isomeric changes now under consideration. Such changes are most frequently observed amongst the oximes and nitro- compounds, but a somewhat similar rearrangement must be assumed to occur in the preparation of amines from amides by Hofmann's reaction and in the decomposition by heat of the acid azides. Although the mechanism of the change is only imperfectly known,[1] the rearrangement resembles very closely that by which radicles are transferred from the side chain to the nucleus in aromatic compounds; in each case isomeric change is usually complete, and is brought about by acid rather than by alkaline agents.[2] Thus, whilst alkaline catalysts greatly accelerate the conversion of normal into pseudo- nitrocamphor, they do not bring about any further change. Acid catalysts, on the other hand, are less powerful in producing pseudo-nitrocamphor, but cause a further non reversible rearrangement of the Beckmann type whereby the nitro-compound is converted into camphoryl oxime



5. *Mechanism of Isomeric Changes involving an Interchange of Radicles.*—These changes appear to be electrolytic in the same sense as the chlorination of ethane, in which *the main constituents can act only as depolarisers* and the electrolyte is probably hydrogen chloride

$$\begin{array}{lccccll} & - & + & & & & \\ C_2H_5 & Cl & H & Cl & & C_2H_5Cl & HCl \\ | & - & + & | & \text{gives} & & \\ H & Cl & H & Cl & & HCl & HCl \end{array}$$

The association of an olefine with HBr may thus take place in a closed electrolytic circuit in which HBr is electrolysed

$$\begin{array}{lccccllcc} & \rightarrow & & \rightarrow & & & & & \\ & - & + & - & & & & + & - \\ R.C.H & Br & H & Br & & R.CH & Br & H & Br \\ \| & + & - & + & \text{gives} & \| & & - & + \\ R.C.H & H & Br & H & & R.CH & H & Br & H \\ & \leftarrow & & \leftarrow & & & & & \end{array}$$

whilst the reverse dissociation might be effected by the passage of a current in the opposite direction, giving rise either to the original or to the isomeric olefine. So also in the aromatic series the conversion of phenylchloroacetamide, $C_6H_5.NCl.CO.CH_3$ into *p* chloroacetanilide, $Cl.C_6H_4.NH.CO.CH_3$, may be regarded as taking place in a circuit

[1] See Steiglitz, *Amer. Chem. Journ.* 1896, **18**, 751; 1903, **29**, 49; Slossen, 1903, **29**, 289; Steiglitz and Earle, 1903, **29**, 399 and 412.

[2] The Hofmann reaction takes place in alkaline solution, but is not an isomeric change, and can therefore hardly be quoted as an exception.

in which hydrogen chloride is electrolysed. But when a methyl-group is transferred there appears to be a complete separation of the radicle (*e.g.* as CH_3Cl) and subsequent recondensation, giving rise not only to isomerides, but also to higher and lower homologues.

6. *Influence of Catalytic Agents.*—Isomeric changes of this type usually take place only in presence of strong acids, whilst alkalies prevent rather than assist the change,[1] as is shown by the stability of the salts derived from labile sulphonic acids, diazohydroxides and oximes, and by the readiness with which good yields of compounds such as phenylchloroacetamide and β-phenylhydroxylamine are obtained by alkaline or neutral methods of preparation. The conversion of ammonium cyanate into urea may be regarded as due to the dissociation of the cyanate and recondensation of the resulting NH_3 and HCNO—

$$NH_4.CNO \rightleftarrows \begin{array}{c} NH_2 \\ | \\ H \end{array} + \begin{array}{c} CO \\ \| \\ NH \end{array} \rightleftarrows \begin{array}{l} NH_2\diagdown \\ \qquad\quad CO\,; \\ NH_2\diagup \end{array}$$

whatever view be taken of this condensation it is evident that the ammonia is resolved into the two radicles H and NH_2, and so functions as an acid rather than as a base; there need therefore be no hesitation in classifying this change with the dissociation and association of acids which characterise this group of isomeric changes.

IV. *Isomeric Changes in which a single Mobile Radicle is Transferred.*

To this group belong all those cases in which a mobile hydrogen atom is transferred from oxygen or sulphur to carbon or nitrogen, as in the ketones, nitro- compounds and oximes, together with the few cases in which it is possible to prepare isomeric salts from these. The transference of an anion is less frequent but Hantzsch has described a number of cases in which a mobile OH or CN group is transferred in precisely the same way as the mobile hydrogen atom. The group of changes in which a mobile hydrogen atom is transferred includes the most important cases of dynamic isomerism and forms one of the most fully investigated, and at the same time one of the most fertile, branches of organic chemistry; the great wealth of examples must be attributed to the neutral character of the hydrogen atom, which is equally ready to play an inert part in a hydrocarbon, or to associate itself with a powerful negative radicle in the mineral and organic acids.

All the members of this group undergo isomeric change with great readiness. This is probably due to the fact that in every case *at least one of the isomerides is an electrolyte*, and so can take its place in an electrolytic circuit instead of acting merely as a depolariser. Thus, although it is difficult to think of pseudo-acetone as anything but an unsaturated alcohol, the proximity of the double bond gives it at least a superficial resemblance to acetic acid and probably confers upon it distinct electrolytic properties:

$$\underset{\text{Acetone}}{CH_3.CO.CH_3} \qquad \underset{\text{Pseudo-acetone}}{CH_3.C\begin{array}{l} \diagup OH \\ \diagdown\!\!\diagdown CH_2 \end{array}} \qquad \underset{\text{Acetic acid.}}{CH_3.C\begin{array}{l} \diagup OH \\ \diagdown\!\!\diagdown O \end{array}}$$

[1] Exceptions to this rule are found in cases in which an interchange of radicles depends on a double ketoenolic change or on a reversible hydrolysis, as in the case of α and β glucose.

The relative stability of the isomerides, depending as it does on the ratios of the velocities of change, is greatly influenced by substitution. The introduction of negative groups appears always to favour the production of the more acid isomeride.

1. *Ketones.*—The mono-ketones are almost wholly ketonic, but their behaviour on bromination[1] and possibly their phosphorescence when exposed to Tesla radiation, or after exposure at low temperatures to ultra-violet light, indicates that even here a trace of enol may be present. The introduction of the CO_2Et group in ethylic acetoacetate makes its chemical properties entirely different from those of acetone, but does not introduce any large proportion of enol into the equilibrium.[2] Amongst the diketones, however, ethyl acetylacetone, $CH_3.CO.CHEt.CO.CH_3$, though almost wholly ketonic at 93°, contains about one-third of enol at 19°; methyl acetylacetone, $CH_3.CO.CH.Me.CO.CH_3$, contains about one-eighth of enol at 96°, and one-half at 16°; whilst acetylacetone itself, $CH_3.CO.CH_2.CO.CH_3$, contains about three-fourths of enol at 93° and at 17° appears to contain a certain amount of a dienolic form

$$CH_3.CO.CH_2.CO.CH_3 \rightleftarrows CH_3.CO.CH : C(OH).CH_3 \rightleftarrows CH_2 : C(OH).CH : C(OH).CH_3$$

Similarly Claisen[3] found amongst the triketones an increasing tendency to enolisation, as benzoyl was displaced by acetyl in the series

$$CHBz_3,\ CHAcBz_2,\ CHAc_2Bz,\ CHAc_3.$$

Camphor, like acetone, is almost wholly ketonic, though it yields an enolic benzoate, $C_8H_{14}\left<\begin{matrix}CH\\ \|\\ C.OBz\end{matrix}\right.$, when boiled with benzoyl chloride.[4] α-Bromocamphor, $C_8H_{14}\left<\begin{matrix}CHBr\\ |\\ CO\end{matrix}\right.$, is only known in the ketonic form, but the flash of light that appears when the crystals are crushed is perhaps an indication of the presence of a trace of the enolic form. Ethyl camphocarboxylate, $C_8H_{14}\left<\begin{matrix}CH.CO_2Et,\\ |\\ CO\end{matrix}\right.$ the analogue of ethyl acetoacetate, is also mainly ketonic,[5] but solutions of α-benzoylcamphor, $C_8H_{14}\left<\begin{matrix}CH.COC_6H_5\\ |\\ CO\end{matrix}\right.$, contain 60 per cent. of the enolic isomeride.[6]

2. *Aldehydes.*—Enolisation of *aldehyde* only occurs when negative radicles are introduced into the methyl group, as in ethers of phenylformylacetic acid,[7]

$$H.CO.CH\left<\begin{matrix}C_6H_5\\ CO_2R\end{matrix}\right. \rightleftarrows HO.CH : C\left<\begin{matrix}C_6H_5\\ CO_2R\end{matrix}\right.$$

and formylacetoacetic acid.[8]

[1] Lapworth, *Trans.* 1904, **85**, 30.
[2] Perkin, *Trans.* 1892, **61**, 801.
[3] *Ann.* 1896, **291**, 25.
[4] Lees, *Trans.* 1903, **83**, 152.
[5] Brühl, *Ber.* 1902, **35**, 3510.
[6] Forster, *loc. cit.*
[7] Wislicenus, *Ann.* 1896, **291**, 147; Lapworth and Hann, *Trans. Chem. Soc.* 1902, **81**, 1491.
[8] *Ber.* 1893, **26**, 2730.

$$\mathrm{H.CO.CH}\left\langle\begin{array}{l}\mathrm{CO.CH_3}\\ \mathrm{CO_2R}\end{array}\right. \rightleftarrows \mathrm{HO.CH : C}\left\langle\begin{array}{l}\mathrm{CO.CH_3}\\ \mathrm{CO_2R}\end{array}\right.$$

Hydroxymethylene (formyl) camphor[1] is usually regarded as the enolic modification, $\mathrm{HO.CH : C}\left\langle\begin{array}{l}\mathrm{C_8H_{14}}\\ \ \vert\\ \mathrm{CO}\end{array}\right.$, and formylacetylacetone,

$$\mathrm{H.CO.CH(CO.CH_3)_2} \rightleftarrows \mathrm{HO.CH : C(CO.CH_3)}$$

is a stronger acid than acetic.

3. *Esters.*—The possibility of enolisation is indicated in the formulæ assigned to ethylic sodiomalonate, $\mathrm{EtO.CO.CH : C(OEt).ONa}$, and ethylic sodiocyanacetate, $\mathrm{CN.CH.C(OEt).ONa}$,[2] and is of importance in determining the optical inversion of carboxylic acids. In the case of ethylic dicarboxyglutaconate, $\mathrm{(CO_2Et)_2C : CH.CH(CO_2Et)_2}$, and ethylic isaconitate, $\mathrm{CO_2Et.CH : CH.CH(CO_2Et)_2}$,[3] the ester itself gives a blue coloration with ferric chloride and is at least partially enolic. The green modification of ethylic succinosuccinate is not represented in a satisfactory manner by either of the conventional formulæ,

$$\mathrm{CO_2Et.CH}\left\langle\begin{array}{l}\mathrm{CO.CH_2}\\ \mathrm{CH_2.CO}\end{array}\right\rangle\mathrm{CH.CO_2Et} \text{ and } \mathrm{CO_2Et.C}\left\langle\begin{array}{l}\mathrm{COH.CH_2}\\ \mathrm{CH_2.COH}\end{array}\right\rangle\mathrm{C.CO_2Et},$$

but the colour would be accounted for if it were formulated as

$$\left.\begin{array}{r}\mathrm{EtO}\\ \mathrm{HO}\end{array}\right\rangle\mathrm{C : C}\left\langle\begin{array}{l}\mathrm{COH{:}CH}\\ \mathrm{CH{:}COH}\end{array}\right\rangle\mathrm{C : C}\left\langle\begin{array}{l}\mathrm{OEt}\\ \mathrm{OH}\end{array}\right. ,$$

and if this be correct the enolised ester is actually the stable form under certain conditions.

4. *Phenols.*—The strong enolic character of the phenols is lessened by substitution and by reduction, probably owing to the weakening of the benzene ring. *Pseudo*-phenol, $\mathrm{O : C_6H_4}\left\langle\begin{array}{l}\mathrm{H}\\ \mathrm{H}\end{array}\right.$ and *pseudo*-quinol, $\mathrm{O : C_6H_4}\left\langle\begin{array}{l}\mathrm{H}\\ \mathrm{OH}\end{array}\right.$ are as unstable as *pseudo*-camphor or *pseudo*-acetone, though derivatives of this type are known,[4] but dihydroresorcinol appears to contain at least one keto-group and yields a dioxime, whilst phloroglucinol yields a trioxime, though its absorption spectrum shows that it is almost wholly enolic in solution.[5]

5. *Amides.*—These rarely, if ever, exist in an enolic form, even when forming part of an aromatic ring as in isatin, the α and γ pyridones (hydroxypyridines),

$$\mathrm{CH}\left\langle\begin{array}{l}\mathrm{CH.C(OH)}\\ \mathrm{CH : CH—}\end{array}\right\rangle\mathrm{N} \text{ and } \mathrm{HO.C}\left\langle\begin{array}{l}\mathrm{CH.CH}\\ \mathrm{CH : CH}\end{array}\right\rangle\mathrm{N},$$

[1] Claisen, *Ann.* 1894, **281**, 306.
[2] J. F. Thorpe, *Trans.* 1900, **77**, 923.
[3] Guthzeit and Dressel, *Ber.* 1889, **22**, 1418.
[4] See especially Auwers, *Ber.* 1902, **35**, 443–455, who gives a summary of recent work on the *pseudo*-quinols.
[5] Hartley, Dobbie, and Lauder, *Trans.* 1902, **81**, 929.

carbostyril (hydroxyquinoline), $C_6H_4\left\langle\begin{array}{l}CH:CH\\ \quad\;\;|\\ N{=}C.OH\end{array}\right.$, and cyanuric acid, $HO.C\left\langle\begin{array}{l}N:C(OH)\\ N.C(OH)\end{array}\right\rangle N$. In all these cases only one modification is known, and Hartley, Dobbie, and Lauder have shown that this is probably the ketonic form.[1] Cyanic and thiocyanic acids also yield isomeric esters, but are only known in one form, apparently the ketonic.[2] Lees and Shedden [3] claim to have prepared the enolic form of acetyl-*o*-aminophenol, $HO.C_6H_4.N:CMe.OH$, but the great stability of the substance, which does not appear to be convertible into the ketonic isomeride, is difficult to reconcile with the formula they propose.

6. *Nitro- compounds.*—These are influenced by substitution in a similar manner to the ketones. Even in aqueous solution the conversion of the pseudo into the normal form appears to be complete in the case of nitromethane, $H.CH_2.NO_2$, nitroethane, $CH_3.CH_2.NO_2$, phenylnitromethane, $C_6H_5.CH_2.NO_2$, and its *p*-bromo- and *p*-nitro- derivatives; but dinitroethane, $NO_2.CH_2.NO_2$, gives a mixture of the normal and pseudo forms, and—in aqueous solution only (see p. 199)—acetylnitromethane $CH_3.CO.CH_2.NO_2$, benzoylnitromethane, $C_6H_5.CO.CH_2.NO_2$, bromodinitromethane, $NO_2.CBrH.NO_2$, and trinitromethane, $(NO_2)_2CH.NO_2$, appear to exist almost exclusively in the pseudo- form.[4]

Similar effects are produced in the camphor series, the nitro- compounds of which have been examined both in ionising and in non-ionising solvents. Nitrocamphane,

$$C_8H_{14}\left\langle\begin{array}{l}CH_2\\ |\\ CH.NO_2,\end{array}\right.$$

passes in solution completely from the pseudo- into the normal form.[5] Nitrocamphor,

$$C_8H_{14}\left\langle\begin{array}{l}CH.NO_2\\ |\\ CO,\end{array}\right.$$

gives a mixture, and in β- and π-bromonitrocamphor,

$$C_8H_{13}Br\left\langle\begin{array}{l}CH.NO_2\\ |\\ CO,\end{array}\right.$$

the influence of the keto- group is so far reinforced by the bromine that in the solid state the pseudo- is the stable form.[6]

7. *Nitroso- compounds and Oximes.*—The group $>CH.NO$ appears to be even more unstable than the pseudo-amide group $-N:COH-$.

[1] *Trans.* 1899, **75**, 640.
[2] Hartley, *Proc. Chem. Soc.* 1899, **15**, 46.
[3] *Trans.* 1903, **83**, 750–763.
[4] Hantzsch, *Ber.* 1899, **32**, 607.
[5] Forster, *Trans.* 1900, **77**, 260.
[6] The stability of the pseudo- form in the solid state is due to a decrease of solubility, and not to any marked increase in the proportion present in solution.

Schmidt[1] has prepared from trimethylethylene three nitroso- compounds, which he formulates as

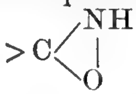
$$\begin{array}{l} CMeH.NO \\ | \\ CMe_2.O.NO \end{array} \qquad \begin{array}{l} CMeH.NO \\ | \\ CMe_2.O.NO_2 \end{array} \quad \text{and} \quad \begin{array}{l} CMeH.NO \\ | \\ CMe_2Cl \end{array} .$$

These are converted by heating or by alkalies into the isomeric oximes, $X.CMe_2.CMe{:}NOH$, but the change proceeds so slowly that there has been some hesitation in accepting the formulæ proposed. The unexpected behaviour of these nitroso- compounds is probably due to the stability of the colourless polymerides, which must be resolved before isomeric change can take place. Piloty's chloronitrosoethane[2] behaves in a precisely similar manner as indicated in the scheme

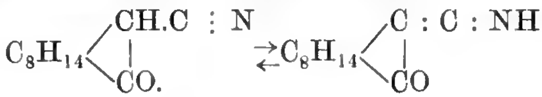
$$[CH_3.CHCl.NO]_2 \rightleftarrows 2CH_3.CHCl.NO \rightleftarrows 2CH_3.CCl : NOH.$$

In the nitrosoaldehydrazones studied by Bamberger and Pemsel[3] the conversion of the nitroso- compound into the oxime involves the change of the hydrazone into an azo- compound, and the stability of the nitroso- compound is greatly increased—

$$CH_3.C(NO) : N.NH.C_6H_5 \rightleftarrows CH_3.C(: NOH).N : N.C_6H_5.$$

The further equilibrium between the hydroximes $>C : NOH$ and pseudoximes  has been so little studied that no definite conclusions can be drawn as to the effects of substitution; in the cases studied by Dr. Whiteley[4] the stability of the two solid forms appears to be determined mainly by their solubility, and nothing is known at present of the proportions in which they are present in the solutions.

8. *Other cases.*—The alkyl *cyanides* are only known in one form, but cyanocamphor appears to exist to some extent in the acid *pseudo-* form,



and *pseudo*-cyanoform is an even stronger acid than *pseudo*-nitroform,[5]

$$CH(CN)_3 \rightleftarrows (CN)_2C : C : NH.$$

Dynamic isomerism is also common amongst the hydrazones and azo- compounds and the amidines. A review of all the groups in which dynamic isomerism has been observed is given by Wislicenus,[6] but the examples quoted above will suffice to show the general character of the observations that have been made.

9. *Isodynamic salts.*—Unlike hydrogen, the metallic radicles have a strong tendency to attach themselves to the most negative groups in the molecule, and isomeric change is usually both rapid and complete. By

[1] *Ber.* 1903, **36**, 1765.
[2] *Ber.* 1902, **35**, 3113.
[3] *Ber.* 1903, **36**, 57–84.
[4] *Trans.* 1903, **83**, 24.
[5] Hantzsch and Ostwald, *Ber.* 1899, **32**, 641.
[6] 'Ueber Tautomerie,' *Ahren's Sammlung*, 1898.

taking advantage of their slight solubility, Titherley has recently prepared the labile silver salts of benzamide and acetamide,[1]

$$C_6H_5.CO.NHAg \rightleftarrows C_6H_5.C(OAg):NH,$$
$$CH_3.CO.NHAg \rightleftarrows CH_3.C(OAg):NH,$$

and Hantzsch has isolated the isodynamic forms of mercuric cyanurate.[2] But whilst it is possible to prepare N and O salts from the amides, the ketones appear to yield only enolic salts, and it is doubtful if metals ever become directly linked to carbon except in the carbides and perhaps the cyanides. Ethyl phenylformylacetate appears at first sight to be an exception, since it yields two series of salts: the enolic sodium salt, $NaO.CH:CPh.CO_2Et$, prepared by the action of sodium on an ethereal solution of the ester, is converted almost instantly when dissolved in water, into an aldehydic isomeride, which gives no coloration with ferric chloride; on the other hand, the solid aldehydic copper salt, when precipitated from aqueous solution, soon passes into an enolic isomeride. The aldehydic salt has always been formulated as $Na.CO.CHPh.CO_2Et$, but there does not appear to be any precedent for the direct displacement of aldehydic hydrogen by metals, and the difficulty entirely disappears if the salt be regarded as derived from an enolised ester (see p. 206):

$$\underset{\text{(enolic salt)}}{NaO.CH:CPh.CO_2Et} \rightleftarrows \underset{\text{(aldehydic salt)}}{H.CO.CPh:C(OEt).ONa.}$$

Dynamic isomerism is also possible, though not yet proved, amongst simple inorganic salts like the sulphites

$$NaO.SO.ONa \rightleftarrows Na.SO_2.ONa.$$

10. *Transference of an Anion.*—In the majority of organic compounds the OH group is devoid of basic properties, and it is only in cases like the ammonium, the sulphur, and the iodine bases that it is capable of functioning as an anion. Occasionally, however, the necessary conditions are fulfilled, and a state of equilibrium may be observed between an ammonium base and an isomeric carbinol, the transference of the hydroxyl- group being exactly comparable with that of the mobile hydrogen atom in the ketones and nitro-compounds.[3] Thus Hantzsch has shown that phenylmethylacridinium hydroxide, when liberated from its salts, is rapidly converted into the neutral isomeric phenylmethylacridol,[4]

$$CPh\left\langle\begin{matrix}C_6H_4\\C_6H_4\end{matrix}\right\rangle \overset{+}{NMe}\,|\,\overset{-}{OH} \longleftarrow HO.CPh\left\langle\begin{matrix}C_6H_4\\C_6H_4\end{matrix}\right\rangle NMe.$$

The case that has been most fully studied is that of the alkaloid cotarnine,[5]

$$C_8H_6O_3\left\langle\begin{matrix}CH:\overset{+}{NMe}\,|\,\overset{-}{OH}\\ \qquad\quad | \\ CH_2.\ \ CH_2\end{matrix}\right. \rightleftarrows C_8H_6O_3\left\langle\begin{matrix}CH(OH).\ \ NMe\\ \qquad\qquad\quad | \\ CH_2 \text{ --- } CH_2\end{matrix}\right. .$$

[1] *Trans.* 1901, **79**, 409. [2] *Ber.* 1902, **35**, 2717.

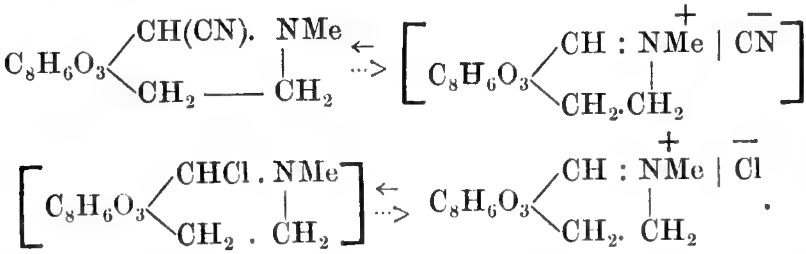
[3] Hantzsch describes as *pseudo- acids* all those substances which, like the nitro-paraffins, are themselves neutral, but yield salts derived from an isomeric acid. Similarly *pseudo- bases* are neutral substances which combine with acids to form salts of an isomeric base. Occasionally the cyano- derivatives (nitrils) of the pseudo-bases (carbinols) can be converted into salt-like isomerides (substituted ammonium cyanides), and these are therefore called *pseudo- salts*. To these three cases Hantzsch applies the term '*ionic isomerism*.'

[4] Hantzsch, *Ber.*, 1899, **32**, 575–600.

[5] Dobbie, Lauder, and Tinkler, *Trans.* 1903, **83**, 598.

The solid alkaloid appears to be the neutral carbinol, and persists in this form when dissolved in ether or chloroform. When dissolved in water or alcohol, however, it is converted largely into the ammonium-base from which the acid salts are derived. The addition of methyl alcohol to the ethereal solution causes a gradual change from the carbinol to the basic form, but a reverse change is brought about by adding sodium hydroxide to the aqueous solution.

A similar equilibrium is possible in the salts derived from cotarnine, but the chloride is known only in the ammonium form and the cyanide only in the carbinol form:

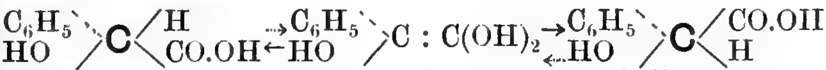


11. *Influence of Catalytic Agents.*—Unlike the isomeric changes of Group A, which usually take place only in presence of an acid catalyst, those involving the transference of a mobile hydrogen atom are characterised by an extraordinary sensitiveness to the catalytic action of traces of *alkalies.* The instantaneous fall of rotatory power on adding a small amount of ammonia to freshly prepared solutions of glucose was noticed by O'Sullivan and Tompson in 1890,[1] but it was not until some years later that the dependence of the mutarotation on isomeric change was demonstrated. Similar effects have been observed in the case of nitrocamphor,[2] nitrocamphane,[3] benzoylcamphor,[4] menthyl acetoacetate, camphorquinone phenylhydrazone,[5] and the azo-derivatives of menthyl acetoacetate,[6] and no exception has yet been discovered. The smaller catalytic action of *acids* was first noticed in the mutarotary sugars,[7] and Osaka[8] has shown that whilst the influence of alkalies is proportional to the concentration that of acids is proportional to the square root only. The influence of acids on nitrocamphor was at first overlooked,[9] though it is well marked in decinormal and centinormal solutions; Lapworth was the first to show that acceleration by acids is characteristic of this group of isomeric changes. An apparent exception occurs in the case of camphorquinone phenylhydrazone, the mutarotation of which is stopped by traces of acid. Neutral *salts* have no influence on the isomeric change of glucose,[10] but greatly accelerate that of nitrocamphor.[11] This difference is probably due to the fact that pseudo-nitrocamphor is a strong acid, and is able to compete for a base even against a mineral acid.

[1] *Trans.* 1890, **57**, 920.
[2] *Loc. cit.* p. 221.
[3] Forster, *Trans.* 1900, **77**, 259.
[4] Forster, *Trans.* 1901, **79**, 999.
[5] Lapworth and Hann, *Trans.* 1902, **81**, 1499 and 1508.
[6] Lapworth, *Proc.* 1903, **19**, 149.
[7] Levy, *Zeit. phys. Chem.* 1895, **17**, 301; Trey, *Zeit. phys. Chem.* 1895, **18**, 193; 1897, **22**, 424.
[8] *Zeit. phys. Chem.* 1900, **35**, 661.
[9] *Loc. cit.* p. 221.
[10] Lowry, *Trans.* 1903, **83**, 1317.
[11] *Loc. cit.* p. 221.

V. *Optical Inversion.*

When optical isomerides become isodynamic the resulting mixture is inactive, for under normal conditions the *d* and *l* forms are equally stable. At least in the case of carbon it appears to be impossible *directly* to alter the point of attachment of the radicles, and the interchange on which the inversion depends can only be effected by an indirect process. In many cases the inversion appears to be brought about by means of a double keto-enolic isomeric change, the inactive enolic form being in equilibrium with both active forms. The proportion of enol is often exceedingly small, and isomeric change must then be slow even under the most favourable conditions. If the mobile hydrogen atom is displaced by methyl the inversion is no longer possible. Thus in the case of *phenylglycollic acid*, which becomes inactive when heated alone,[1] or with dilute alkalies,[2] the inversion is probably effected through the intermediate inactive form indicated in the equation

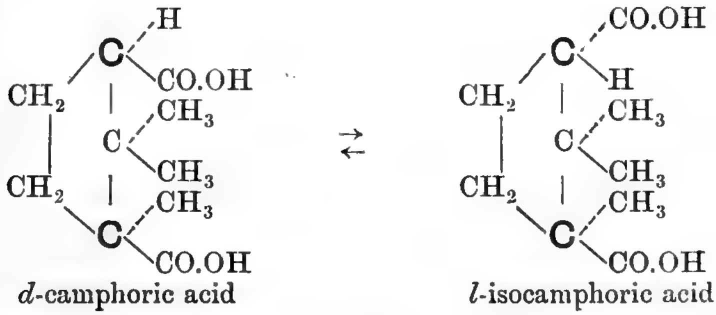


d-acid (50 per cent.) inactive enolic acid (trace) *l*-acid (50 per cent.)

A similar explanation may be given of the conversion of maleic into fumaric acid, since this also involves the interchange of H and CO_2H.

Although changes of the keto-enolic type are exceedingly sensitive to alkaline catalysts the optical inversion of acids is often brought about more rapidly by acid catalysts, on account perhaps of the greater stability of the ketonic form in the metallic salts. The esters (see p. 206) would probably be racemised even more easily than the acids but for the fact that it is impossible to introduce either acids or alkaline catalysts without hydrolysing the ester. Kipping and Hunter[3] have shown, however, that although *benzylmethylacetic acid*, $C_6H_5.CH_2.CHMe.CO_2H$, is unchanged when heated at 170° during two hours, the *acid chloride* is racemised slowly at 70° and rapidly at 100°, and this may be taken to indicate that the chloride, unlike the acid, contains an appreciable quantity of enol.

d-Camphoric acid, which contains two asymmetric carbon atoms, undergoes a reversible isomeric change when heated with water or with a mixture of acetic and hydrochloric acids. Only one of the asymmetric carbon atoms carries a hydrogen atom, and this is readily inverted, giving rise to a mixture of *d*-camphoric and *l*-isocamphoric acids in unequal proportions.

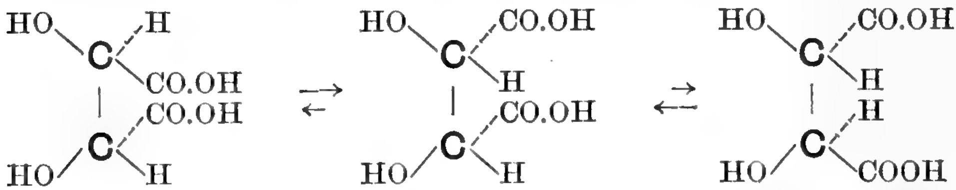


d-camphoric acid *l*-isocamphoric acid

[1] Lewkowitsch, *Ber.* 1883, **16**, 2721.
[2] Holleman, *Rec. Trav. Chim.* 1898, **17**, 323.
[3] *Trans.* 1903, **83**, 1009.

The second asymmetric carbon atom is not inverted, and *no l-camphoric acid is produced.* It is therefore possible, by merely converting into an anhydride, to restore completely the original activity of the acid.

In *d-tartaric acid* both active carbon atoms can be inverted, giving rise to *meso*-tartaric and *l*-tartaric acids. The rate of formation of the *meso-* acid from the $d+l$ acid in presence of hydrochloric acid at 140° is 1·9 time as great as that of the $d+l$ from the *meso-* acid, and the proportions in the equilibrium are therefore those indicated in the equation



d- acid 17·3 % *meso-* acid 65·4 % *l-* acid 17·3 %

The formation of the *meso-* acid involves a double, and that of the *l-* acid a quadruple keto-enolic change, and the conversion is therefore exceedingly slow, the proportions after heating during 42 hours at 155° being only 3·4 % *l* : 18 % *meso* : 78·6 % *d*.[1] The salts undergo similar isomeric change when heated with an excess of alkali, but the proportions when equilibrium is reached appear to be 38 % *l* : 24 % *meso* : 38 % *d*.

The reversible isomeric change which *gluconic and allied acids* undergo when heated with quinoline or pyridine at 130°–150° [2] is of importance, not only in the synthesis of the sugars but also because of the proof it affords that a definite mechanism is needed to bring about optical inversion, and that apart from this it is impossible even to interchange the points of attachment of an H and OH group. In each case *only the terminal CHOH group which carries the carboxyl is inverted,* whereas if it were possible by this drastic treatment to shake the remaining CHOH groups the product would be a chaotic mixture of the sixteen acids which are theoretically possible.

Closely related to the isomeric changes of the sugar-acids are those which the *hexoses* themselves undergo in solution, and especially in presence of alkalies. Glucose appears to exist in four isodynamic forms,[3] of which the stereoisomeric α and β (hydrogen-) glucosides are the dominant forms and the aldehyde a minor constituent, the enol being present only in traces. Owing to the moderate proportion of aldo-glucose present in the solution equilibrium is rapidly established between the α and β glucosides. The enolic form is common to glucose, fructose, and mannose, and the slow rate at which equilibrium is established between these three sugars, even in the presence of considerable quantities of alkali,[4] is an

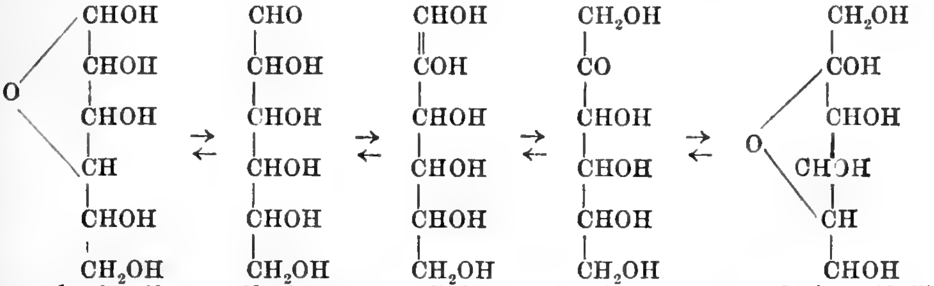
[1] Holleman, *Rec. Trav. Chim.* 1898, **17**, 66.

[2] Fischer, *Ber.* 1894, **27**, 3193.

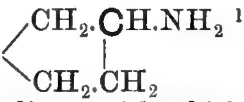
[3] Compare *Trans.* 1903, **83**, 1314. For the proof that the α and β glucose are the parent substances of the α and β glucosides, see E. F. Armstrong, *Trans.* 1903, **83**, 1305, and Behrend and Roth, *Ann.* 1904, **331**, 359. With reference to the proportions of the constituents in the mixture, see Lowry, *Proc.* 1904, **20**, 108. For the dynamic isomerism of the methyl glucosides and of the pentacetates, see Jungius, *Proc. Kon. Akad. Wet.* Amsterdam, 1904, 99 and 779.

[4] Lobry de Bruyn, *Rec. Trav. Chim.* 1895, **14**, 201.

indication of the minute proportion of enol in the mixture. It is of interest to note that the complete equilibrium may include no less than ten isomeric sugars.

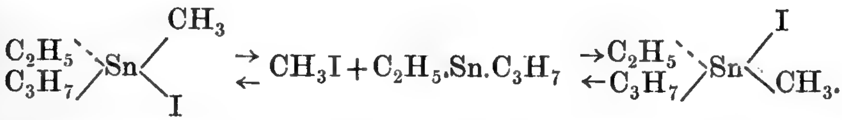


α and β glucoside α and β mannoside (?) — aldo-glucose aldo-mannose — enolic form of glucose, mannose, and fructose — keto-fructose — α and β fructoside (?)

The inversion of *tetrahydro-β-naphthylamine*, C_6H_4  [1] involves the interchange of H and NH_2, and the readiness with which it takes place at ordinary temperatures is in marked contrast with the great stability of compounds containing the CHOH group. It can scarcely be supposed that the replacement of OH by NH_2 destroys the fixity of the four carbon valencies, and the isomeric change may perhaps depend on the dissociation of an ammonium hydroxide base in the sense of the equation

$$>CH.NH_2 + H_2O \rightleftarrows >CH.NH_3.OH \rightleftarrows H_2O + >C:NH_3 \text{ (inactive).}$$

The salts do not appear to undergo optical inversion. Another case in which the optical isomerides are in equilibrium at ordinary temperatures is that of the *d* and *l methylethylpropylstannic iodides*,[2] in which isomeric change probably depends on dissociation.

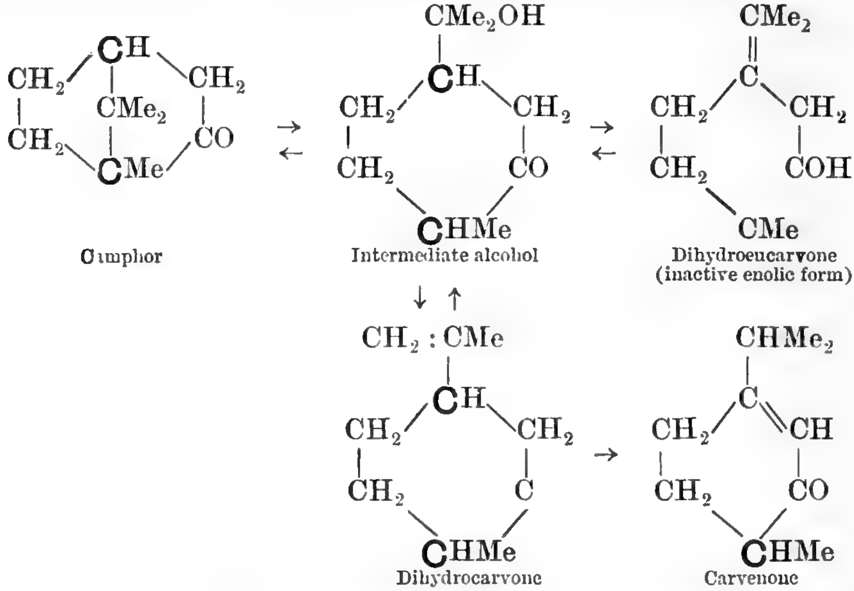


These cases are of importance as indicating that the 'spontaneous' racemisation, frequently postulated in the so-called '*chaotic*' molecules, may actually exist as a limiting case of dynamic isomerism.

The *optical inversion of camphor* during sulphonation[3] necessitates the rupture of one of the three chains which connect the asymmetric carbon atoms, and occurs under conditions very similar to those which actually lead to the production of carvenone.[4] The inactive dynamic isomeride through which inversion is accomplished is perhaps the enolic form of dihydroeucarvone, which, like dihydrocarvone and camphor itself,

[1] Pope and Harvey, *Trans.* 1901, **79**, 74.
[2] Pope and Peachey, *Proc.* 1900, **16**, 116.
[3] Kipping and Pope, *Trans.* 1897, **71**, 958.
[4] Bredt, *Annalen*, 1901, **314**, 369.

may be produced by removing the elements of water from the alcohol formulated below.[1]



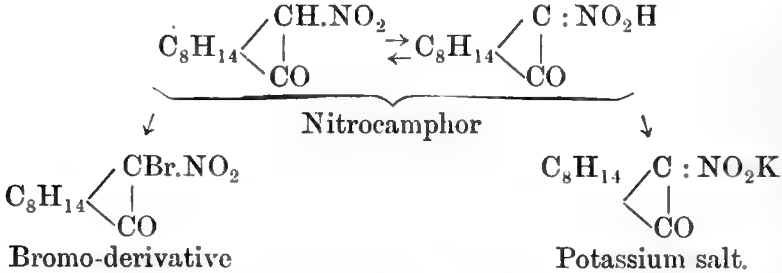
Camphor — Intermediate alcohol — Dihydroeucarvone (inactive enolic form) — Dihydrocarvone — Carvenone

VI. *Chemical Properties of Dynamic Isomerides.*

The addition to a mixture of isomerides in equilibrium of an agent which forms a stable compound with one isomeride brings about a complete conversion into that form. Thus although ammonium cyanate can be converted completely into urea by evaporating its aqueous solution, the reverse change is readily brought about by digesting urea with silver nitrate.

$$(NH_2)_2CO \rightleftarrows AmCNO \rightarrow AgCNO$$

Again, nitrocamphor can be converted equally readily and completely into the bromo- derivative of the normal form or the potassium salt of the pseudo form.



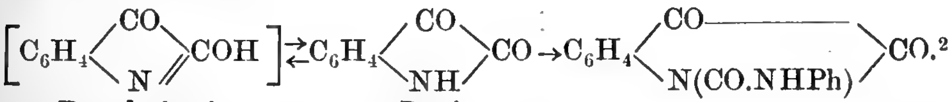
Bromo-derivative — Potassium salt.

This formation of two types of derivatives is one of the most important indications of dynamic isomerism, and is frequently observed even when only one of the isomerides can be isolated. Thus camphor and other ketones, which certainly do not yield more than the merest trace of enol, are readily converted into enolic benzoates[2] when boiled with benzoyl chloride; again, although the conversion of pseudo into normal

[1] Armstrong and Lowry, *Trans.* 1902, **81**, 1469. [2] Lees, *Trans.* 1903, **83**, 152.

nitrocamphane is so complete that the pseudo- form cannot be detected in the equilibrium, no difficulty is experienced in reconverting it into the potassium salt of the pseudo- form.

Chemical agents, therefore, give very little information as to the nature of the equilibrium, and can only be used for separating the constituents when isomeric change proceeds slowly under the prevailing conditions. Thus no difficulty is experienced in separating ammonium thiocyanate and thiourea or a mixture of sulphonic acids, because at ordinary temperatures and in dilute solution these have no tendency to pass into one another, and are, in fact, no longer isodynamic. So also Küster was able to separate the isomeric hexachlorocycloketopentenes by converting the β- compound into the sparingly soluble anilide, $C_6H_5.NH.C_5Cl_5O$. In the case of substances such as those described in Section IV., in which the transference of a mobile radicle takes place with the utmost readiness under ordinary conditions and at atmospheric temperatures, the majority of chemical agents are useless for this purpose, especially as many of them have a very powerful catalytic action, and greatly accelerate the isomeric change. The only agent that seems to fulfil the necessary conditions is *phenyl isocyanate*,[1] which has little or no catalytic action, and may even remove any moisture or acid impurity already present in the solution; experimentally it has been found that it combines with phloroglucinol but not with ethyl succinosuccinate, indicating that the former is enolic but the latter wholly ketonic; the same agent indicates that isatin is a ketone, since it gives a substituted urea and not a urethane.



Pseudo-isatin Isatin

Benzylidene aniline, $C_6H_5.CH:N.C_6H_5$, although equally ready to combine with ketones or enols, cannot be regarded as a trustworthy indicator, for the addition of a trace of sodium ethoxide appears to determine the formation of the enolic, whilst piperidine favours the formation of the ketonic addition-product quite independently of the proportions of ketone and enol present in the mixture.[3]

A different class of agent is typified by ferric chloride, which interacts only with a minute proportion of the hydroxylic isomeride to form a coloured ferric salt. If this were insoluble a complete conversion into the hydroxylic form would ensue, but when it remains in solution it does not seriously disturb the equilibrium, and so may serve to indicate the proportion of hydroxyl present.

$$.CH_2.CO. \rightleftarrows .CH:COH \rightleftarrows .CH:C(OFeCl_2).$$

In the case of the simple nitro-paraffins and isodynamic ketones ferric chloride can be used to follow the gradual conversion of one form into the other, but in the case of the nitro-ketones it has such a powerful catalytic action that equilibrium is established immediately, and no difference can be detected either in the intensity of the colour or the rapidity

[1] Goldschmidt, *Ber.* 1890, **23**, 257.

[2] This conclusion is in agreement with that arrived at by Hartley from a study of the absorption spectra.

[3] Schiff, *Ber.* 1898, **31**, 601.

with which it is developed on adding ferric chloride to the normal and pseudo forms of π-bromonitrocamphor.[1]

Similar limitations are met with in the *preparation of labile isomerides by chemical methods.* The hydroxylic forms of many diketones[2] and nitroparaffins[3] can be prepared by acidifying a cold aqueous solution of the sodium salt with dilute mineral acids. In these cases the addition of a mineral acid is sufficient to eliminate the catalytic action of the base originally present in the salt, but stronger acids like pseudo-nitrocamphor are able to retain a proportion of the base even in competition with a mineral acid, and in this case the catalytic action of neutral salts is so great that the product is always a mixture of isomerides and not the pseudo- form. This action of neutral salts appears to have been overlooked by Hantzsch, who concluded that benzoylnitromethane and bromodinitromethane existed only in the hydroxylic form in aqueous solution, a conclusion that was based entirely on the fact that no gradual decrease of conductivity was observed in freshly prepared mixtures of the sodium salts with hydrochloric acid.

Another method of preparing a labile isomeride is indicated by Forster, who has succeeded in preparing the labile diketonic form of benzoylcamphor by boiling the enolic modification with formic acid, precipitating with water, and rapidly crystallising from alcohol;[4] the method appears to depend on the formation of an easily hydrolysed formyl derivative,

$$C_8H_{14}\begin{cases} C(COPh)CHO \\ \vert \\ CO, \end{cases}$$

and may perhaps be applicable in other cases.

VII. *Physical Properties of Dynamic Isomerides.*

1. *Crystallography.*—In the majority of cases dynamic isomerides are substances of different types, and do not form isomorphous mixtures, though this does not prevent the inclusion in a crystal of small amounts of a dynamic isomeride or the staining of a colourless crystal by a coloured isomeride. Thus normal π-bromonitrocamphor is tetragonal and has $a : c = 1 : 1{\cdot}1002$, whilst the pseudo- form is orthorhombic and has $a : b : c = 1 : 1{\cdot}2159 : ?$[5] Again, although both forms of a-benzoylcamphor crystallise in the orthorhombic system the ketone has $a : b : c = 0{\cdot}7375 : 1 : 1{\cdot}0224$, but the enol has $a : b : c = 0{\cdot}9728 : 1 : 0{\cdot}6550$, and is hemihedral.[6]

2. *Crystallisation of Fused Dynamic Isomerides.*[7]—In the absence of

[1] Lowry, *Trans.* 1899, **75**, 230.

[2] Claisen, *Ann.* 1896, **291**, 25; W. Wislicenus, *Ann.* 1896, **291**, 147; Knorr, *Ann.* 1896, **293**, 70; J. Wislicenus, *Ber.* 1897, **30**, 639; *Sitz. Sächs. Akad.* March 1, 1897; Rabe, *Ber.* 1899, **32**, 84.

[3] Hantzsch and Schultze, *Ber.* 1896, **29**, 699, 2251; Konowalow, *ibid.* p. 2193; Holleman, *Rec. Trav. Chim.* 1895, **14**, 121; 1896, **15**, 356, 365; Forster, *Trans.* 1900, **77**, 258.

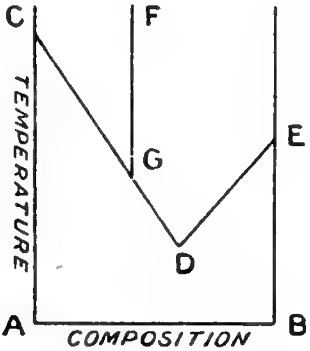
[4] *Trans. Chem. Soc.* 1901, **79**, 997.

[5] Lapworth and Kipping, *Trans.* 1896, 304–322.

[6] Forster, *loc. cit.*

[7] The crystallisation of dynamic isomerides has been very fully discussed from the standpoint of the phase rule by Bancroft (*Journ. phys. Chem.* 1898, **2**, 143, 245), by Roozeboom (*Zeit. phys. Chem.* 1899, **28**, 289) and by Findlay (*Trans.* 1904, **85**, 403), but some modification of the theory is necessary in order to allow for the fact that dynamic isomerism is only possible in a tri- or tetra-molecular system.

dimorphism the freezing-point curve for a mixture of two isomerides A and B has the well-known V-shaped form shown in the figure. When equilibrium exists between them the melt has a definite composition GF, which does not vary much with the temperature. The form that separates first on cooling is determined by the intersection of F G with C D E ; in the figure this lies on the branch C D and the form A is the first to crystallise. If crystallisation is slow or isomeric change rapid, the composition of the liquid and the temperature will remain constant until the whole of the substance has crystallised out in the form A. Slow cooling thus brings about a complete isomeric change, whilst sudden chilling would give a solid of the same composition as the liquid mixture G ; usually the product will be intermediate in composition, but the exact proportions will depend on the melting-points of the isomerides, the composition of the liquid mixture, the velocity of isomeric change, and the rate of



cooling. The temperature G at which one form is in stable equilibrium with the liquid mixture is called the 'equilibrium temperature,'[1] and is readily determined as the temperature at which the substance remelts after fusion.

3. *Fusion. Isomeric Change of Solids. Stability Limits.*—Each isomeride has a characteristic melting-point which is independent of isomeric change. The melting-point of the stable isomeride which separates first on cooling the melt is necessarily above the 'equilibrium temperature,' whilst that of the labile isomeride may be either above or below this temperature. In the case of β- and π-bromonitrocamphor the constants are :—

	π	β
m.p. of normal	108°	?
m.p. of pseudo	142°	132°
equilibrium temperature	124°	100°

the pseudo being the stable form in each case. When the melting-point lies above the equilibrium temperature it can be observed by rapidly heating a crystal and noting the temperature at which it fuses ; if heated slowly the crystal may melt gradually at a temperature only just above the equilibrium temperature, but in this case the fusion is a consequence of isomeric change, and will take place more and more slowly as the purity of the substance is increased. If the melting-point lies below the equilibrium temperature the fused substance will (if sufficiently impure to permit of isomeric change) soon solidify owing to the separation of crystals

[1] Lowry, *Trans.* 1899, 75, 233.

of the stable isomeride, which will again melt when the equilibrium temperature is reached; frequently the melting and resolidification proceed simultaneously, and only a slight sintering is observed in the neighbourhood of the melting-point.

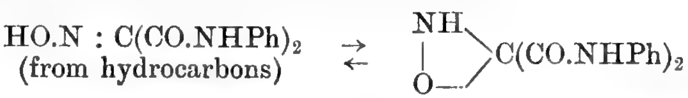
Although in the liquid state each isomeride is equally labile when alone, and equally stable when equilibrium is attained, in the solid state only one isomeride can be stable at any given temperature, namely that which has the least vapour pressure; this is usually that which has the highest melting-point, but the opposite case is not infrequently observed. In the absence of a catalyst the labile isomeride may be preserved indefinitely, and may even be fused without undergoing isomeric change, but usually the change commences before the melting-point is reached, and at a temperature depending on the amount of impurity present in the crystals. This temperature Knorr has described as the *stability limit*,[1] but it cannot be regarded as a physical constant of the substance as Knorr at first supposed, and his later work has shown that in the purified material the stability limit becomes identical with the melting-point.[2]

4. *Dissolution.*—Each isomeride has a *true solubility* which is independent of isomeric change, and may be determined by measuring the concentration of the solution obtained when the solid and solvent have been in contact during a period of time sufficient for saturation, but not long enough for isomeric change to produce any marked effect. Ultimately, however, a condition is reached in which the solution contains a stable mixture of the isomerides and is saturated with regard to one of them. The *apparent or ultimate solubility*[3] is thus dependent on the true solubility and the composition of the mixture in equilibrium.

The measurement of the initial and final solubility affords a method of determining the composition of the mixture. Thus in the case of β-bromonitrocamphor the initial solubility at 10° C. is 2 grams per 100 c.c. of benzene, and the final solubility 8 grams per 100 c.c.; and it may, therefore, be inferred that in the ultimate mixture the isomerides are present in the ratio 1 : 3 approximately.[4] The method has the advantage of being applicable even when only one of the isomerides can be isolated.

5. *Crystallisation from Solutions.*—The form that separates first on evaporating or cooling a solution is that which has the smallest apparent solubility. Usually it will be the major constituent of the mixture, but the minor constituent may separate if its true solubility is small. Slow crystallisation will then result in complete isomeric change, whilst rapid crystallisation will yield a mixture from which the constituents can sometimes be separated by picking out the crystals mechanically.

The order of solubility can sometimes be reversed by changing the temperature or the solvent, or both, and in this way it may be possible to isolate and purify more than one isomeride. Thus Dr. Whiteley has shown[5] that the yellow hydroxylic modification of isonitrosomalonanilide separates from chloroform or benzene, but the white pseudoxime from ethyl acetate, methyl alcohol, ether, or acetic acid,



(from hydrocarbons) (from oxygenated solvents).

[1] *Ann.* 1899, **306**, 70 and 88.
[2] Wislicenus, 'Ueber Tautomerie,' footnote, p. 225.
[3] Lowry, *Trans.* 1899, **75**, 231.
[4] Lowry, *Proc.* 1903, **19**, 156.
[5] *Trans.* 1903, **83**, 34.

Precisely similar changes are observed in the case of isonitroso-*p*-chlorobenzyl cyanide,

$$Cl.C_6H_4.C(CN):NOH \rightleftarrows Cl.C_6H_4.C(CN)\!\left\langle{NH \atop O}\right| \quad (?),$$

which crystallises from alcohol or water in colourless needles, but passes into a yellowish-green isomeride when kept or when crystallised from petroleum. The sodium salt also exists in a colourless and a yellow form.[1]

In a somewhat similar manner Tanret[2] by crystallising from alcohol at a high temperature isolated a low-rotatory form of glucose isomeric with that which separates at ordinary temperatures.

Piutti and Abati have recently prepared a white and a yellow modification of *p*-methoxyphenylphthalimide,[3] which they regard as merely dimorphous; but the difference in colour and the behaviour on heating indicate that the two forms are probably dynamic isomerides, and may be formulated as the symmetrical and unsymmetrical imide,

$$\underset{\text{(colourless)}}{C_6H_4\left\langle{CO \atop CO}\right\rangle N.C_6H_4.OMe} \rightleftarrows \underset{\text{(yellow).}}{CO\left\langle{C_6H_4 \atop O-}\right\rangle C:N.C_6H_4.OMe}$$

From boiling alcohol the yellow form separates, but the white form is stable in contact with benzene at ordinary temperatures. In the case of the reduced compound, *p*-methoxyphenyltetrahydrophthalimide,

$$C_6H_8\left\langle{CO \atop CO}\right\rangle N.C_6H_4.OMe \rightleftarrows CO\left\langle{C_6H_8 \atop O-}\right\rangle C:N.C_6H_4.OMe,$$

the white form crystallises from all solvents below 70°, and the yellow form above 70°; and this appears to be a fairly definite transition temperature.

Polymorphism.—If isomeric change is rapid the crystallisation of dynamic isomerides obeys the same laws that govern the crystallisation of polymorphous substances, and it becomes very difficult to distinguish the two phenomena. In at least two important cases dynamic isomerides have been first described as mere polymorphs, and it is probable that in other cases the polymorphism is due to differences in molecular structure. A rearrangement of the molecules in the crystal can scarcely produce any marked alteration in colour, and a difference so striking as that between yellow and red mercuric iodide must be associated with some difference in molecular structure.

6. *Physical Methods of Studying Dynamic Isomerism. Mutarotation.*—(1) In some cases it is possible to determine whether a liquid substance is a single compound or a mixture of isomerides in equilibrium by calculating the physical constants of the possible isomerides and noting whether the substance gives a value agreeing with one of these or intermediate in magnitude. Unfortunately the constants that can be calculated are few in number, and do not vary much in isomeric compounds; moreover, the accumulation of negative groups gives rise to abnormally high optical constants, and the observed values often lie right outside the calculated

[1] Zimmermann, *J. pr. Chem.* 1902, ii, **66**, 353.
[2] *C. R.* 1895, **120**, 1060.
[3] *Ber.* 1903, **36**, 1000.

limits. Statical methods of this kind are, therefore, of little use in detecting dynamic isomerism, and their chief value consists in the information that they give as to the constitution that must be assigned to the dominant form of the parent substance and to its isomeric derivatives. Thus Brühl,[1] by measuring the *molecular refraction and dispersion*, has shown that hydroxymethylene (formyl) camphor is mainly enolic, but its bromo-derivative has the aldehydic constitution :—

$$C_8H_{14}\left\langle\begin{array}{l}C : CH.OH\\ \mid\\ CO\end{array}\right. \rightarrow C_8H_{14}\left\langle\begin{array}{l}CBr.CHO\\ \mid\\ CO\end{array}\right.$$

and, again, that ethyl camphocarboxylate is mainly ketonic, whilst its acetyl- derivative is enolic.[2]

$$C_8H_{14}\left\langle\begin{array}{l}CH.CO_2Et\\ \mid\\ CO\end{array}\right. \rightarrow C_8H_{14}\left\langle\begin{array}{l}C.CO_2Et\\ \parallel\\ C.OAc\end{array}\right.$$

Perkin[3] has also made use of the *magnetic rotatory power*, a property that has the advantage of being much more sensitive to changes of structure ; thus, whilst the calculated molecular refractions of the two forms of ethylic phenylformylacetate differ by less than 2 per cent., the magnetic rotations of the two possible forms of ethyl acetoacetate differ by 20 per cent. ; some of the results obtained by this method have already been indicated (p. 203). (2) An analogous method depends on the fact that the composition of the stable mixture may be influenced to a very considerable extent by physical conditions, and properties like the molecular refraction and the magnetic rotation which are normally almost independent of temperature, solvent, and concentration may vary widely when the material examined is an isodynamic mixture. Such variations may indicate the existence of dynamic isomerism,[4] though similar effects are produced by reversible polymeric change and by association with the solvent. (3) A more sensitive method of detecting dynamic isomerism consists in following the physical changes which accompany isomeric change. In the case of a pure liquid compound the physical properties reach a constant value as soon as the temperature and other physical conditions are steady, but the existence of a time-factor is a sure indication of chemical change. Thus, when ethylic acetoacetate is distilled the proportions of the isomerides are altered, and some hours elapse before the substance recovers its normal density,[5] though the total change only amounts to 0·0013 gram per c.c. Since crystallisation normally results in the complete separation of one of the isomerides a maximum amount of isomeric change is observed when the crystals revert to the liquid state either by fusion or by dissolution. Thus it is sometimes possible by repeated fusion to follow the gradual fall in the melting-point as the homogeneous crystals revert to an equilibrium mixture, but usually isomeric change is so rapid that a single fusion is sufficient to bring about a condition of equilibrium. Dissolution has the advantage that observations can be made at atmospheric temperatures, and that isomeric change then proceeds much more slowly than in the fused state, but the properties of the solute are often very seriously

[1] *Zeit. phys. Chem.* 1900, **34**, 31–61.
[2] *Ber.* 1902, **35**, 3510.
[3] *Trans.* 1892, **61**, 801.
[4] Perkin, Brühl, *loc. cit.*
[5] Schaum, *Ber.* 1898, **31**, 1964.

disguised by admixture with the solvent. Thus it would be almost impossible to detect with certainty the slight change in density or refractive index which would result from a partial isomeric change in solution, and the change in magnetic rotatory power, though still appreciable, would be much smaller than in a fused substance. For this reason the method of dissolution only gives the best results when the physical property utilised has a zero value in the case of the solvent, and differs considerably in the different isomerides. These conditions are fulfilled by (1) conductivity, (2) optical rotation, (3) solubility, (4) colour.

The *electrical conductivity* has been used with remarkable success by Hantzsch,[1] who has followed the gradual decrease of conductivity in solutions of the pseudo-nitroparaffins and similar compounds, freshly prepared by mixing a solution of the sodium, barium, or silver salt with a mineral acid—*e.g.* :—

$$\overset{+}{H}\,|\,\overset{-}{Cl} + CH_3.CH:\overset{-}{NO_2}\,|\,\overset{+}{Na} \rightleftarrows \overset{+}{Na}\,|\,\overset{-}{Cl} + CH_3.CH:\overset{-}{NO_2}\,|\,\overset{+}{H}$$
$$\rightleftarrows \overset{+}{Na}\,|\,\overset{-}{Cl} + CH_3.CH_2.NO_2.$$

Unfortunately the method is somewhat limited in its application, and cannot readily be applied to substances that are insoluble in water, or are only feeble electrolytes.

Perhaps the most generally applicable method is that which consists in observing the *mutarotation* of freshly prepared solutions of optically active bodies. The isomerides usually differ widely in rotatory power, and observations can be made in any solvent and in fairly dilute solution. The rapidity and accuracy with which measurements can be made render it possible to detect changes involving only a small percentage of the material or taking place so rapidly that equilibrium is reached in the course of a few minutes. Moreover, the conditions are such that the behaviour of highly purified materials can be successfully investigated. The method has already been applied in a large number of typical cases, and can be extended to nearly every type of isomeric change.

Hitherto the *solubility* has only been utilised in a limited number of cases,[2] but the method, though more tedious and perhaps less accurate than those just described, is even more widely applicable, and has the unique advantage that it gives information as to the proportions of the isomerides in solution, even when only one of these can be isolated.

The recent observations of Dobbie, Lauder, and Tinkler on the ultra-violet absorption-spectra of cotarnine[3] show that *colour* may be made the basis of a quantitative method, and the valuable results that have been obtained justify the hope that the method will be applied in many other cases.

7. *Colour.*—As a qualitative method the colour of dynamic isomerides has proved most valuable in indicating the occurrence of isomeric change, and it has the unique merit of rendering visible to the eye the progress of isomeric change both in the solid and in the liquid state. Moreover, since it has become possible to associate colour with definite types of structure, and even roughly to predict the probable colour of a compound having a given formula, it is often possible to determine, by means of the colour, the constitutions that must be assigned to a series of solid

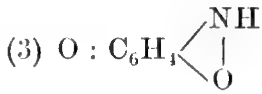
[1] *Ber.* 1896, **29**, 699, 2256; 1899, **32**, 607, 628, 641.
[2] Lowry, *Proc.* 1903, **19**, 156; *Proc.* 1904, **20**, 108. [3] *Trans.* 1903, **83**, 598.

isomerides. Thus it is noteworthy that the earliest indication of the possible existence of hydroxylic pseudonitro compounds was based upon observations of colour-change, and the suggestion made by Armstrong in 1892,[1] in order to account for the coloured salts of the nitrophenols, has been abundantly justified by the subsequent investigations of Nef, Hantzsch, and others. According to this view the colourless ethers have formulæ of the type $EtO.C_6H_4.NO_2$, whilst the coloured salts are formulated as $O : C_6H_4 : NO_2K$; in the liquid state the nitrophenols themselves may exist in both forms,

$$HO.C_6H_4.NO_2 \rightleftarrows O : C_6H_4 : NO_2H,$$

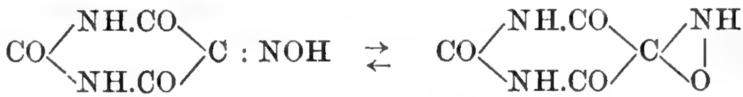
but the colourless needles of *p*-nitrophenol must be represented by the first, and the quinone-like crystals of *o*-nitrophenol by the second formula.

Again, of the compounds represented by the formulæ—

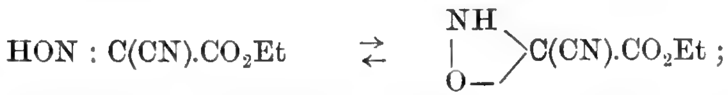
(1) $HO.C_6H_4.NO$ (2) $O : C_6H_4 : NOH$ (3) 

the first should be blue or green like the *o* and *p* ethers, $MeO.C_6H_4.NO$;[2] the second should be red like the sodium salt, $O : C_6H_4 : NONa$, or yellow like the benzoyl- derivative $O : C_6H_4 : NOBz$, whilst the third should be colourless like the pseudoquinols. The substance produced by the action of nitrous acid on phenol or of hydroxylamine on quinone separates from ether in green flakes, and gives a green solution in water, alcohol, or ether, which must contain at least a considerable proportion of the nitroso- compound (1) ; the colourless needles which separate from aqueous solution may be a dimolecular form of the nitroso-compound (p. 224), but must otherwise be represented by the third formula.

The difference in colour between the yellow hydroximes and the colourless pseudoximes, observed by Dr. Whiteley in the derivatives of isonitrosomalonamide, has already been referred to ; a similar explanation may be given of the colour-changes observed in violuric acid and its salts (Hantzsch and Isherwood),



and in ethylic isonitrosocyanacetate and its salts[3]



in each case, however, the authors regard the coloured compounds as containing the group $\begin{array}{l}—C—O\\ \;\;\; | \;\;\;\; | \\ —C—N.OH,\end{array}$ though this group would scarcely be likely to give rise to colour.

8. *Absorption Spectra.*—Whilst valuable results are obtained by merely noting the colour of dynamic isomerides, data of much greater

[1] *Proc. Chem. Soc.* 8, 101. [2] Baeyer and Knorr, *Ber.* 1902, 35, 3034.
[3] Müller, *Bull. Soc. Chim.* 1902, iii. 27, 1019.

value are afforded by a detailed study of their absorption spectra. Attention has already been called to the observations of Hartley and of Dobbie and Lauder, but further reference must be made to the recent work of Baly and Desch.[1] These authors have shown that neither of the ethyl- derivatives of ethyl acetoacetate give absorption bands, and conclude that the absorption of light by ethyl acetoacetate depends directly on the occurrence of oscillatory isomeric change. They even suggest that the intensity of the absorption band is a direct indication of the rate at which the reversible isomeric change is proceeding. This theory of the origin of colour is in accord with the fact that nearly all coloured substances can be represented by two formulæ, and that colour is most frequent amongst aromatic compounds in which a migration of the linkages is of frequent occurrence. If this view should be confirmed by subsequent observations it would form a most important application of the theory of dynamic isomerism.

9. *Luminosity.*—Whilst colour may perhaps depend only on the selective absorption of light-energy by certain groups of atoms, many of the phenomena of luminosity appear to be directly due to the interconversion of dynamic isomerides.[2]

The simplest of these is the flash of light that is sometimes observed when a crystal is crushed or powdered, and which in organic compounds is usually associated with one of the structures that give rise to dynamic isomerism. Thus saccharine and menthylphenylformylacetate, which give an exceedingly brilliant flash,[3] are normally ketonic compounds, though their solutions may contain a trace of the labile enolic isomeride

$$C_6H_4 < {CO \atop SO_2} > NH \quad \rightleftarrows \quad C_6H_4 < {COH \atop SO_2} > N$$

$$CHO.CHPh.CO_2R \quad \rightleftarrows \quad HO.CH : CPh.CO_2R.$$

During rapid crystallisation a small amount of the enolic form may be entangled in the crystals, and the flash of light appears to be due to the energy liberated when the labile form undergoes isomeric change at the moment of crushing.

Fluorescence appears to be a modification of this phenomenon in which the labile isomeride is continuously reproduced by the action of ultraviolet light, and phosphorescence may be regarded as fluorescence taking place in a viscous medium which will only permit a gradual reversion to the stable form. The relationship between fluorescence and dynamic isomerism has been discussed by Hewitt,[4] and the nature of phosphorescence may be illustrated by reference to the ketones, which become brilliantly phosphorescent after exposure to ultra-violet light at low temperatures (Dewar), probably owing to the liberation on warming of energy stored up at low temperatures in the labile enolic form.

VIII. *Reversible Polymeric Change.*

Reversible polymeric changes obey nearly all the laws that govern reversible isomeric change, and give rise to phenomena similar to those that have been described in the preceding sections. But whilst reversible

[1] *Trans.* 1904, **85**, 1029.
[2] Armstrong and Lowry, *Proc. Roy. Soc.* 1903, **72**, 258.
[3] Pope, *Trans.* 1895, **67**, 985; Lapworth, *Trans.* 1902, **81**, 1495.
[4] *Proc. Chem. Soc.* 1900, **16**, 3; *Zeit. phys. Chem.* 1900, **34**, 1.

isomeric changes are limited to a comparatively small group of substances, reversible polymeric changes occur very frequently, not only in complex organic compounds, but also in the simplest inorganic substances, including even the elements. Perhaps the most notable difference consists in the fact that equilibrium is largely influenced, and indeed mainly determined, by the temperature and pressure, conditions which produce only small changes in the equilibrium between dynamic isomerides.

In most cases equilibrium is attained almost instantaneously. The properties of freshly melted ice are perfectly normal, and the depolymerisation of N_2O_4 is so rapid that it is not possible to detect any time-factor. Amongst organic compounds, however, gradual changes have occasionally been noticed. Formaldehyde shows a slow decrease of molecular weight in freshly diluted solutions,[1] and freshly diluted or freshly cooled solutions of gelatine only slowly assume their normal viscosity. The most striking examples of gradual changes of this type are to be found amongst the organic nitroso- compounds which exist in a blue or green monomolecular and a colourless dimolecular form.[2] In the case of nitrosobutane, CMe_3NO, Bamberger and Seligman[3] have plotted a complete curve showing the gradual depolymerisation in a solution in benzene at the freezing-point; equilibrium is reached in four hours, and the decrease of molecular weight proceeds simultaneously with the development of the blue colour.

There is reason to believe, however, that under favourable conditions gradual association and dissociation are not infrequent amongst simple inorganic compounds. Only in this way can the remarkable facts be explained that have been noted by many observers in studying the critical phenomena of gases, and to which attention has recently been called by Traube.[4] Thus, when liquid carbon dioxide is heated above its critical temperature, the upper and lower layers of gas, though easily miscible, remain distinct for a considerable period of time, and only gradually diffuse into one another. Under apparently identical conditions the density of the gas may vary in the ratio of 1 : 2·16. So also when the gas is cooled from above its critical temperature, neither the liquid nor the vapour has at first its normal density; the meniscus is gradually displaced through several centimetres, equilibrium being attained only after a week has elapsed. Traube explains these results by assuming the existence of 'gasogenic' and 'liquidogenic' molecules, but the variation of physical properties with time, to which reference has been so frequently made in the preceding pages, affords clear evidence of the occurrence of chemical change, and it can scarcely be doubted that the phenomena, *if not due to inequalities of temperature or pressure*, afford indications of a reversible polymeric change similar in character to, but slower than, those which take place so rapidly in the case of water and of nitrogen peroxide.

[1] Inaug. Diss. Rostoch, Eschweiler; *Abstr.* 1890, 954.

[2] Meyer, *Ber.* 1888, **21**, 507; 1896, **29**, 94; Thiele, *Abstr.* 1894, i. 217; Baeyer, *Abstr.* 1894, i. 252; Piloty, *Ber.* 1898, **31**, 218, 221, 452, 457, 1878; 1902, **35**, 3113; 1903, **36**, 1297; Schmidt, *Ber.* 1903, **36**, 1765; Bamberger and Rising, *Ber.* 1901, **34**, 3877.

[3] *Ber.* 1903, **36**, 689.

[4] *Ann. d. Physik*, 1902, **8**, 2, 267.

The Movements of Underground Waters of North-west Yorkshire.—Fifth Report of the Committee, consisting of Professor W. W. WATTS (*Chairman*), Mr. A. R. DWERRYHOUSE (*Secretary*), Professor A. SMITHELLS, Rev. E. JONES, Mr. WALTER MORRISON, Mr. GEORGE BRAY, Rev. W. LOWER CARTER, Mr. T. FAIRLEY, Professor P. F. KENDALL, *and* Dr. J. E. MARR.

THE Committee are carrying on the work in conjunction with a committee of the Yorkshire Geological and Polytechnic Society.

It will be remembered that at the Southport meeting the Committee reported that the work of tracing the streams sinking on the slopes of the Ingleboro' massif was complete, with the exception of a few small streams.

These have now been traced, and the work of the Committee is therefore completed, with the exception of the boreholes at Turn Dub mentioned below.

The work done during the current year consists of tracing the following streams by means of fluorescein.

East Side of Ingleboro'.

1. The stream sinking at P 14,[1] near the shooting-box on the Allotment, which had been unsuccessfully tested on several previous occasions, was found to issue at Austwick Beck Head (S 28).

2. A small stream to the north of last, sinking at P 18, passes by P 19, where the fluorescein was visible, to S 40, there joining the water from P 25 and P 26, previously tested.

3. The small stream sinking at the 'Washfold' (P 52) on Park Fell was found to communicate with the channel from Alum Pot to Footnaws Hole (S 65), where the water was strongly coloured three days after the fluorescein was introduced at P 52. Footnaws Hole, as has been previously shown, discharges in normal weather at Turn Dub (S 67).

West Side of Ingleboro'.

4. P 93. The water from a group of small streams near Douk Cave on Fenwick Lot, Souther Scales Fell, flows underground along the direction of the master joints in the limestone, and issues at S 106*a*, a small spring below Eller Keld.

5. The water from P 97 and P 98 on Souther Scales Fell flows to a small spring and cave known as Far Douk, but not marked on the 6-inch Ordnance Map, P 95*a*, and then again goes underground to join the river, somewhere on its underground course from Weathercote Cave to God's Bridge.

6. P 101 and P 102 on Black Shiver Moss receive the waters of two small streams, the flow being to the lower end of Mere Gill Hole, where it joins the waters of Mere Gill, and again goes underground. The further course of this stream has been described in a previous report.

7. P 102*a* on the eastern edge of Lead Mines Moss, not marked on the 6-inch map, receives a small stream in wet weather only.

This, on being tested with fluorescein, was found to communicate with S 116 near the 'Engine Sheds' at the Ingleton Granite Quarries.

[1] The letters and numbers refer to maps published in the previous reports of the Committee.

A number of boreholes have been put down in the neighbourhood of Turn Dub (see previous reports), the result being that a thickness of from 7 to 8 feet of boulder clay has been proved below the present river-bed.

This, it is considered, is sufficient to account for the passage of the underground water below the surface stream.

The boreholes are still in progress, and the Committee therefore seek reappointment, with permission to retain the unexpended balance.

A full account of the work of the Committee will be published in the Proceedings of the Yorkshire Geological and Polytechnic Society.

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Dr. J. E. MARR (*Chairman*), Dr. WHEELTON HIND (*Secretary*), Mr. F. A. BATHER, Mr. G. C. CRICK, Dr. A. H. FOORD, Mr. H. FOX, Professor E. J. GARWOOD, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. B. N. PEACH, Mr. J. T. STOBBS, Mr. A. STRAHAN, *and* Dr. H. WOODWARD. (*Drawn up by the Secretary.*)

THE Secretary once again regrets that he has received no reports from the large majority of the members of the Committee.

Work has been done by Mr. J. T. Stobbs in three districts. He has again generously given his time, and therefore the grant is only debited with travelling and out-of-pocket expenses.

It was found impossible owing to mining difficulties to work the marine band which occurs in the North Staffordshire Coalfield below the Gin Mine coal. But for the sum of a few shillings a trench was dug across the strike and the beds were exposed in succession. The marine band was exposed and some few fossils were collected, but the bed was much weathered by proximity to the surface, and it was found inadvisable on this account to make any prolonged search for fossils. However, the position of the marine band with regard to the Gin Mine coal, a subject on which in the course of years a curious error had arisen, was definitely settled. Sections and a list of fossils obtained are given in Mr. Stobbs's report.

As excavations for waterworks were being carried on in the Valley of the Derwent Mr. Stobbs went there to examine the cuttings in the Pendleside Series, the upper portion of which was then exposed. A detailed report follows.

It was also thought good to examine the northern boundary of the South Wales Coalfield, and as far as possible to collect from the small coal workings, confined to single seams. In the recent resurvey of the South Wales Coalfield palæontology does not seem to have had the attention paid to it which it deserves. The grant therefore has only been partially used, and the Committee ask that the balance may be retained for future work.

Personally, while collecting in the Carboniferous district of the Midlands, the Secretary has been examining the Devonian Carboniferous succession in the south-west of Ireland and North Devon, the results of which are expressed in a paper published in the 'Geological Magazine' for August 1904.

It is well known that the Carboniferous Limestone in South-west

Ireland gradually dies away south-west of Cork, and in the succession at Old Head of Kinsale, and from that point westward no Limestone whatever occurs, but instead there is a thick mass of Grits and Slates, which have been called Lower Limestone Slates and Coomhola Grits. It is also known that the passage up from the Devonian Grits to Coomhola Grits is unbroken, and that the one series has no top and the other has no base. The Coomhola Grits are, however, fossiliferous and contain shells referred to *Ptychopteria Damnonensis*, *Cucullæa unilateralis*, species which occur in the Pilton and Marwood series of Devonshire. These beds are always classed as Upper Devonian in England, and therefore it would be well for the same line to be drawn in Ireland. The whole fauna from the Coomhola Grits should be re-examined, because I think it probable that trilobites and other species have been referred to Carboniferous forms on the supposition that the Coomhola beds were Carboniferous. The Coomhola Grits are overlaid by the Lower Carboniferous Slate, part of which is indeed of Carboniferous age, because it contains *Posidonomya Becheri*. Here then is a point of great interest. Beds with a Marwood and Pilton fauna are overlaid by grey shales and then by black with *P. Becheri*; and in North Devon the Pilton beds are succeeded by the Lower Culm with *P. Becheri* in abundance in the Venn Limestones. In both districts the Devonian Carboniferous succession, apparently unbroken and conformable, is from Marwood and Pilton beds to Pendleside Series, the Carboniferous Limestone being absent in each locality; and if there is no unconformity it follows that the Carboniferous Limestone was never laid down in the North Devon, Cork, and Kerry latitude.

Jukes considered that the Carboniferous Slate of South-west Ireland was contemporaneous with the Carboniferous Limestone, and his views are given at length, pp. 33–37 of the 'Memoir of the Geological Survey' (Ireland), Explanations of Sheets 187, 195, 196 of the maps. He visited North Devon and says: 'I saw that both lithologically and palæontologically, bed for bed, and fossil for fossil, the Braunton and Piltown rocks of Devon were identical with the Carboniferous slate of Cork. The Marwood sandstones and the grey grits below them that form Baggypoint were obviously the same as our Coomhola Grits, and the red and green rocks that rise up from beneath those rocks in Morte Bay are exactly similar to the Upper Old Red Sandstone of large parts of the west of County Cork.

'But the Coal Measures' (by which I suppose he means the Culm, and I would that all subsequent geologists had recognised the Coal Measure horizon of these beds) 'of Devon rest on the Carboniferous slate without intervention of any Carboniferous Limestone in its ordinary form, often without any appearance of limestone at all.' But he carries his argument too far, for he goes on to say: 'If, however, we have Coal Measures above and Old Red Sandstone below, the rocks between them must be of the age of the Carboniferous Limestone.'

The Lower Culm is, I am convinced, of later age than the Carboniferous Limestone, and is the homotaxial equivalent of the Pendleside series. How comes it, therefore, that the Coomhola Grits and the grey portion of the so-called Lower Carboniferous Slate are mapped as Carboniferous instead of Upper Devonian?

The view advanced by Jukes, that the Carboniferous Slate is contemporaneous with the Carboniferous Limestone, is probably correct, the

slate consisting of two portions—the lower grey or Upper Devonian, the upper black or Pendleside or Upper Carboniferous. There is no evidence of an overlap, but it must be remembered that the rocks of South-west Cork are nearly vertical, and have been much moved, and I believe the Upper or Posidonomya beds and part of the Carboniferous Limestone is a synclinal with the limbs absolutely in contact, so that the beds in the centre are doubled on themselves.

During last winter Mr. J. G. Hamling, F.G.S., of Barnstaple, kindly sent me for examination a large suite of fossils collected from the Coddon Hill beds of the Lower Culm. These so interested me that I felt it necessary to visit the locality, which I did under his skilled guidance. The Lower Culm of North Devon consists of two series of rocks, neither of them apparently very thick, but much folded and repeated. The Coddon Hill beds are thin laminated, white or fawn-coloured silicious beds, with the following fauna :—

TRILOBITES—	
**Phillipsia polleni ?*	H. Woodward.
,, *spatulata*	H. Woodward.
Proëtus coddenensis	H. Woodward.
**Palæacis humilis*	Hinde.
Pleurodictyum dechanianum	Kayser.
Petræa, cf. *P. pauciradialis*	Phill., sp.
**Productus plicatus*	Sarres.
**Chonetes laguessiana*	de Kon.
**Ortholetes crenestria*	Phill., sp.
**Athyris ambigua*.	
**Prolecanites compressus*	Sow., sp.
* ,, *mixololus*	Phill., sp.
**Pterycyclus* sp.	
* ? *Stroboceras sulcatus*	Phill., sp.
* ? *Nomismoceras spirorbis*.	,, ,,
**Chænocardiola footii*	Baily, sp.
Radiolarians.	
Crinoid stems.	

Those species marked with an asterisk (*) occur in the lower part of the Pendleside series.

The other beds of the Lower Culm are the Venn Limestones, a series of black carbonaceous limestones, with

Posidonomya becheri, Low.	*Glyphioceras crenistria*, Phill., sp.
Pseudamusium fibrillosum, Salter, sp.	,, *sphæricum*, Phill., sp.
Glyphioceras spirale, Phill., sp.	*Orthoceras* sp.

It is a point of difference amongst writers on the Culm as to whether the Posidonomya limestones are above or below the Coddon Hill beds. I believe for stratigraphical reasons that the Coddon Hill beds are at the base and the Venn Limestones succeed them, and also because the Palæontological succession in Derbyshire has beds with *Prolecanites compressus* at the base and *Posidonomya Becheri* immediately above them. In my paper in the 'Geological Magazine,' *op. supra cit.*, I have gone into the stratigraphical question in detail.

Immediately overlying the *Posidonomya beds*, if I am correct, are a series of Middle Culm grits, with occasional vegetable remains, what I consider to be the homotaxial equivalents of the Millstone Grit, because they are intercalated between beds with *Prolecanites compressus* and *Posidonomya Becheri* and the series of clays and shales which are well

seen at Instow, where in a bed of calcareous bullions the following fossils occur :—

Gastrioceras listeri, Mart., sp.
" *carbonarium*, v. Buch.
Dimorphoceras gilbertsoni, Phill.
Orthoceras sp.
Pterinopecten papyraceus, Sow., sp.
Posidoniella lævis, Brown., sp.
Cœlacanthus elegans, Newb.
Elonichthys aitkeni, Traq.

The fauna is one which I regard as characteristic of the marine part of the Gannister Series of the Lower Coal Measures.

The beds above the Instow series have a wonderfully familiar appearance to one acquainted with the Coal Measures, and I am glad to say that Mr. E. Newell Arber has read a paper at the Royal Society which conclusively proves from the flora contained in them that the Culm-bearing series round Bideford is of Middle Coal Measure age.

This is borne out by the occurrence of *Carbonicola acuta* at Roberts quarry, near Bideford, immediately above a rich plant bed, with well-preserved Middle Coal Measure ferns. It must remain at present an open question whether the Carboniferous Limestone is represented in the Culm series by a few feet of calcareous shales and a band or two of limestone, which is seen on the foreshore near Fremington Station. The limestone also being exposed at Fremington Pill Quarry is open to question. The shales on the foreshore contain species of *Brachiopoda*, which are common to the Upper Devonian and Lower Carboniferous.

There are, therefore, four life-zones in the Culm—

Zone of *Carbonicola acuta* and Middle Coal Measure plants.
Zone of *Gastrioceras listeri* and *G. carbonarium*.
Zone of *Posidonomya becheri*.
" *Prolecanites compressus*.

which definitely fix the age of the Culm of North Devon.

This fossil evidence is of importance from an economic view, for it definitely shows that the beds of Culm are the representatives of the coal seams, and that any occurrence of coal in Devonshire is altogether improbable.

The line of strike of the Mendip anticlinal and the Coddon Hill series have a similar relation to each other that the Carboniferous Limestone of Cork and Killarney has to the Devonian Carboniferous succession of the Old Head of Kinsale and Coomhola, and the absence of Carboniferous Limestone south of a fairly definite line is noticed in Devonshire and South-west Cork and Kerry. This condition of things points to a similarity of physical causes in both areas.

An important paper by Mr. Vaughan, F.G.S., 'On the Palæontological Sequence of the Carboniferous Limestone of the Bristol Area,' was read before the Geological Society in June. The paper is not yet published, and I hesitate to criticise it; but in any Carboniferous area with which I am acquainted the fossils chosen by Mr. Vaughan as denoting zones and sub-zones—with one exception, that of *Modiola lata*, a variety probably of *M. macadami*—all occur together at several horizons.

To quote 3.—*Productus semireticulatus*, *P. cora*, *Schizophoria resupinata*, and *Spiriferina octoplicata* occur practically at all horizons in the same beds.

It is, however, a subject of congratulation that work is being commenced on palæontological lines in the Bristol and Mendip area.

The zonary divisions established by Mr. Vaughan are given in the following table. (This is the form in which these divisions are finally set out after emendation and further revision of a preliminary working system.)

	Zones	Sub-zones and Horizons	
		ε	
VISÉAN	DIBUNOPHYLLUM . . .	(D$_2$) *Lonsdaleia floriformis.* (D$_1$) *Dibunophyllum cylindricum.*	
	SEMINULA	(S$_2$) *Productus cora* (mut.). (S$_1$) *Productus semireticulatus.*	(Caninia-Zone.)[1]
		δ	
TOURNAISIAN		(C) Syringothyris, sp. nov.	
		γ	
	ZAPHRENTIS	(Z$_2$) *Schizophoria resupinata.* (Z$_1$) *Spirifer* aff. *clathratus.*	
		β	
	CLEISTOPORA	(K$_2$) *Spiriferina octoplicata.* (K$_1$) *Productus*, sp. nov.	
		α	
	MODIOLA	(M) *Modiola lata.*	

For example: *Productus Cora*, *P. semireticulatus*, and *Schizophoria resupinata* range as high as the upper 300 feet of the Pendleside Series in Cheshire. The first two fossils occur in the Calciferous Sandstone Series of Fife, *P. Cora* in the Ardens limestone, and *P. semireticulatus* and *Schizophoria resupinata* all through the Calciferous Sandstone Series. All three of these fossils occur throughout the Yoredale Series of Wensleydale.

Spiriferina octoplicata is found with all the above species at Castleton and Park Hill, Derbyshire, in the upper beds of the series, and in Fife is found throughout the Carboniferous Limestone Series and as low down as the encrinite bed in the Calciferous Limestone Series.

Lonsdaleia floriformis is not found in the upper beds of the limestone in Derbyshire, but in the main or great limestone of Weardale occurs with the three forms of Brachiopoda mentioned above.

Dibunophyllum cylindricum occurs in the Lower Limestone Series of the West of Scotland with *Lonsdaleia floriformis*, and also some way down in the Upper Limestone Series of the North-west of Ireland. It will be a curious anomaly if the distribution of the species in the isolated patch of Bristol and the Mendips is totally different from that which obtains in all other districts of Great Britain.

Up to the present I have looked in vain for any species of organism which denotes a definite Horizon in the Carboniferous Limestone Series of Great Britain.

It must be noted that in Belgium the Viséan is characterised by the presence of *Productus giganteus*, a shell absent in the Tournaisian.

[1] Employed throughout the preliminary working system.

In the Midlands and Scotland *P. giganteus* occurs throughout the whole of the Carboniferous Limestone Series, which makes it doubtful whether there is any representative of the Tournai Limestone there.

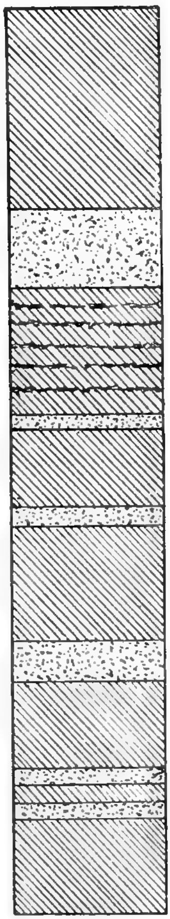
In a paper published in the 'Geological Magazine,' December 4, vol. v. p. 61, I referred to the anomalies of distribution throughout the Carboniferous deposits of Europe of the various species of Brachiopoda which have been stated to denote various horizons in Belgium and Russia.

Owing to the deep trenching, necessary for the construction of a reservoir by the Derwent Valley Water Board in N. Derbyshire, an unusual opportunity was presented of examining the upper portion of the Pendleside Series, which consists mainly of dark laminated shales and thin sandstones.

By the favour of Mr. E. Sandeman, M.Inst.C.E., we were enabled to inspect the sections and the material which was being excavated on a large scale, and to collect therefrom.

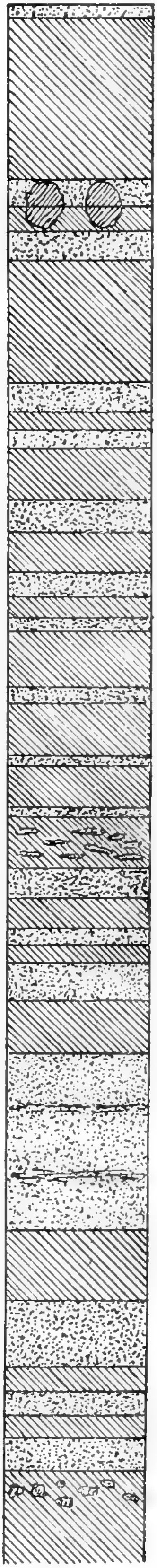
The lower trench, where the work of excavation was mostly proceeding at the time, cuts at right angles the bottom of the valley of the river Derwent, a little to the south of Hollinclough Farm, and the following section was exposed at this point :—

FIG. 1.



	ft.	in.
1. Shales	7	0
2. Grit	2	9
3. Shales, with five thin grit bands . .	4	6
4. Grit		5
5. Shales	2	9
6. Grit		7
7. Shale	4	0
8. Grit	1	3
9. Shale	3	0
10. Grit		6
11. Shale		5
12. Grit		5
13. Shale	3	0

	ft.	in.
14. Grit		2
15. Shales	6	0
16. Grit, with large calcareous bullions .	1	0
17. Shale, with large calcareous bullions .		9
18. Grit	1	0
19. Micaceous shales	4	6
20. Grit	1	0
21. Compact shale		7
22. Argillaceous sandstone		6
23. Shale	1	8
24. Grit	1	3
25. Compact shale	1	6
26. Thinly bedded grit		8
27. Micaceous shale		10
28. Grit		4
29. Shale	2	0
30. Thinly bedded grit		6
31. Shale	1	10
32. Grit		$\frac{3}{4}$
33. Shale	1	7
34. Grit		$\frac{1}{2}$
35. Shales with lenticles of grit . . .	1	10
36. Grit		10
37. Shale with thin pipes of coal . .	1	3
38. Grit		5
39. Shale		7
40. Grit	1	4
41. Shale	1	9
42. Grit in three beds	6	9
43. Micaceous shale	2	6
44. Grit	2	4
45. Micaceous shale		10
46. Grit		9
47. Shale		10
48. Grit	1	0
49. Shale with nodules	Base not seen.	



The bed '*15. Shales*' was highly fossiliferous, yielding the following forms :—

Orthoceras sp.	*Pterinopecten papyraceus*, Calamites sp.
Goniatites, indeterminable species of.	*Posidoniella lævis* (large).

Resting on '*18. Grit*' were numerous large ellipsoidal calcareous bullions, some of which measured 2 ft. 6in. and 1 ft. 6 in. along their major and minor axes respectively. As a rule the bullions contained numerous goniatites, and in one of them was found a fine specimen of *Acrolepis Hopkinsi.*

In '*17. Shales*' *Posidoniella lævis* and *Glyphioceras reticulatum* were fairly abundant.

From '*21. Shales*' *Glyphioceras reticulatum* was collected.

'*25. Compact shale*' contained large *Pterinopecten papyraceus* and *Posidoniella lævis* in great numbers.

'*27. Micaceous shale*' contained *Pterinopecten papyraceus*, *Posidoniella lævis*, *Orthoceras* sp., and *Goniatites* of indeterminable species.

In the middle of '*29. Shale*' was a layer containing *Pterinopecten papyraceus.*

'*33. Shale*' contained *Glyphioceras reticulatum.*

'*35. Shales with lenticles of grit*' were very fossiliferous ; *Posidoniella lævis*, *Pterinopecten papyraceus*, *Glyphioceras reticulatum*, and Goniatite sp. were collected.

'*41. Shale*' contained Calamites sp.

'*43. Micaceous shale*' contained fragmentary plant remains.

The upper trench had been similarly cut across R. Derwent, a short distance above the Abbey Farm, in measures higher in the series, where the shales were thinner and the grits were thicker and formed an increasing proportion of the strata.

The succession revealed by these two trenches corresponds with the shales and sandstones towards the base of the eastern scarp of Mam Tor, near Castleton, Derbyshire.

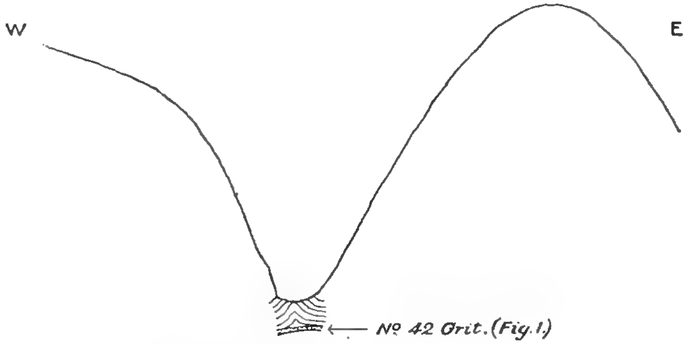
The difficulty in getting continuous sections of Pendleside shales, owing to their disturbed character and to the fact that they are commonly exposed at the bottom of valleys, has been frequently observed. Some light was thrown on the subject by the position of the beds in these trenches. Figs. 2 and 3 show the relation of these disturbances to the valley and hills, as seen in the lower trench, the same general features of which were to be observed in the upper trench also.

The distance between the two trenches, measured in a straight line, is about $1\frac{3}{4}$ mile, and the strata forming the bed of the river are thrown into an anticlinal fold with subsidiary wrinklings in both instances. These foldings are shown in fig. 3 to be confined to the strata near the surface, which consist of the softer and more incoherent shales, whilst the hard and thick grit (No. 42 in fig. 1) may be observed to have resisted the crush movement and forms a fairly level floor to the excavation.

An examination of the ground renders improbable the idea that both the trenches intersect the same anticline, and remembering that both sections occur at the bottom of deep and narrow valleys one is forced to regard the 'wrinkle' and the valley itself as being related in some way as cause and effect. There can be no doubt that considerable 'side-thrust' would result from the weight of these hills, which naturally would make itself felt most on those beds forming the bottom of the valley,

which would, if insufficiently rigid, be crushed and crumpled, and thus prepared for rapid erosion by the stream or river. So that whilst in the

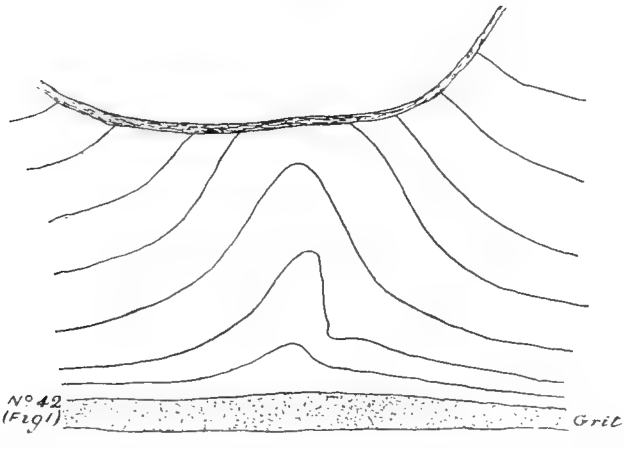
Fig. 2.



Scales: Horizontal, 12 inches per mile.
Vertical, 400 feet per inch.

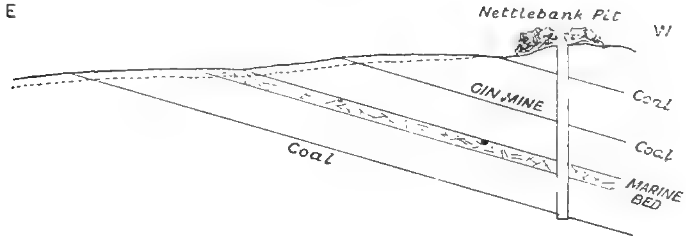
early stages the incipient valley induced the side-thrust of the hills, and the consequent 'crushing' of the measures in the way indicated, the latter

Fig. 3.



has undoubtedly reacted by powerfully promoting the deepening of the valley.

Fig. 4.



Scale: 2 chains per inch.

In the North Staffordshire Coalfield it was deemed desirable to find the outcrop of a rich marine bed known to exist about the horizon of the

Gin Mine Coal. Permission to cut a trench for this purpose on their estate near Smallthorne was kindly given by Messrs. R. Heath & Co., to whom we are under great obligation. Our thanks are also due to Mr. W. Lockett for assistance and advice.

The horizon was reached and its relation to the coal seam, and also its succession of life-forms, exactly made out. This was of great importance, since our previous conceptions required inversion. It was rather disappointing, however, to find the richest part of the horizon, consisting of a very impure and earthy limestone, to be so decomposed on the hillside, where we were working, that the fossils were incapable of preservation, and often of identification. So that the proposal to work the bed on a larger scale at this point was abandoned. The general section is shown in fig. 4, and the following is the succession of the measures constituting the 'marine bed,' together with the fossils restricted to each stratum, so far as could be ascertained, viz.—

	ft.	in.
(1) Dark shale		6
(2) Impure limestone	2	9
(3) Dark shale	7	9

(1) contains—

Lingula mytiloides, Discina nitida.

(2) contains—

Productus semireticulatus, Athyris ambigua, Chonetes Laguessiana, Nucula gibbosa, Ephippioceras costatum, Raphistoma junior, Pleuronautilus armatus, Pleuronautilus n. sp. (with tubercles).

(3) (upper layer) contains—

Archeocidaris Urei, crinoid ossicles, *Loxonema* sp., *Turbonellina*, cf. *T. formosa, Orthoceras pygmæus, Pseudamusium fibrillosum, Nuculana acuta, Ctenodonta lævirostris.*

At base :—

Pterinopecten papyraceus, Posidoniella sulcata.

In South Wales collecting was done on the northern outcrop of the Carboniferous rocks, and the opportunity was taken of examining the 'patchworks' of the Coal Measures in that district. There is no doubt that great discrimination and experience are required in collecting from 'patchworks,' and serious errors have arisen in the past from the work of spoil-heap collectors. This is the more to be regretted, since in no other circumstances do we find such a quantity of material available for search and inspection.

Owing to the personal uncertainty as to the name of the coal seam from whose associated measures the fossils have been derived the position of the 'patch' where they were found will be given in terms of latitude and longitude picked off the 1-inch Ordnance maps, so that the localities may be of assistance to other workers. The horizons will be taken in descending order.

A few feet below the outcrop of the Soap-vein on the patchworks,

west of Rhymney (51° 45′ 35″ N., 3° 18′ 5″ W.), there is a thin clayband ironstone which contains in great abundance—

? Scaldia minuta or Estheria. *Naiadites ?*

This band should form a good index-bed.

Lower down on the same patchworks, near the horizon of the Elled Coal, south of Brynpwllog (51° 45′ 45″ N., 3° 18′ 0″ W.) were found :—

Anthracomya modiolaris (common). *Carbonicola acuta.*

From the roof of the Ras Las Coal, No. 2 Pit, Fochrhiw, the following were obtained :—

Carbonicola aquilina (common). *Naiadites modiolaris.*
Naiadites carinata „

From the patchwork near Dowlais (51° 45′ 35″ N., 3° 20′ 15″ W.), at the horizon of the 9-foot coal, the following were collected :—

Anthracomya modiolaris. *Naiadites carinata* (common).
Carbonicola aquilina (common).

The Ras Las Coal has been regarded as identical with the 9-foot coal, and the above lists support this correlation.

At a level near Hirwaun (51° 45′ 5″ N., 3° 31′ 5″ W.), about the horizon of the Cnapiog Coal, fine specimens of *Carbonicola robusta* were abundant.

In the roof-shale of a thin coal (4 inches thick) which occurs above the grit overlying the engine coal, where it outcrops south of Clydach Colliery, the following plant remains were found :—

In an exposure of black shales in the W. bank of R. Rhymney, a few yards north of Blaen Rhymney, were found—

Anthracomya pumila. *Beyrichia arcuata.*
Carbonicola acuta (numerous). *Cœlacanthus lepturus.*
Naiadites modiolaris.

These black shales are in the so-called Millstone Grit Series.

In dark shales in the same series of rocks a horizon, about 15 inches thick, is exposed in the banks of the stream S. of Garth (51° 46′ 15″ N., 3° 20′ 65″ W.), and contains—

Carbonicola acuta (abundant). *Carbonia* sp.

A little higher in the series and farther up the stream to the east, in dark shales, about 2 feet thick, the following list was obtained :—

Solenomya primaeva. *Edmondia* sp.
Ctenodonta laevirostris. *Lingula mytiloides.*
Nucula aequalis.

Higher again in the series, near Pitwellt Pond (51° 46′ 45″ N., 3° 20′ 30″ W.), another marine bed was seen, yielding—

Lingula mytiloides. *Posidoniella laevis.*

Quarries opposite Clydach on S. side of R. Clydach showed the following sequence in the Carboniferous Limestone :—

1. Blue limestone in thick beds, with thin black shales intervening.
2. Purple and green marl with calcareous nodules, 15 feet thick.
3. White limestone, oolitic and very pure.

In the upper blue limestone, which is only used for road metal, the following were collected :—

Productus hemisphericus.
,, *semireticulatus.*
Fenestella sp.
Lithostrotion aranaea.
,, sp.

In the intervening black shales were obtained —

Leiopteria lunulata.
Productus margaritaceus.
Athyris ambigua.

At a quarry at Blackrocks, in an oolitic portion of the limestone, is a grit bed containing—

Athyris subtilita (abundant).
,, *ambigua.*
Lithostrotion aranaea.

In some of the very thin black shales are—

Productus hemisphericus.
Athyris ambigua.

In the limestone beds at Morlais Quarries were found—

Productus cora (with spines).
,, ,, (without spines).
Orthotetes crenistria.
Spirifer sp.
Euomphalus sp.
Bellerophon sp.
Lithostrotion sp.
Fragments of Brachiopods.

The limestone at Graig Fawr, near Cefn, contains in its upper beds—

Myalina sp.
Athyris ambigua (abundant).
Orthis sp.
Orthotetes crenistria.
Productus cora (abundant).
,, *giganteus* (young).
,, *longispinus.*
Spirifer sp.
Euomphalus sp.
Macrocheilina acuta.
Bellerophon sp.
Archeocidaris Urei (plate).
Crinoids.

Whilst it would be premature to generalise from what has been done in South Wales, the remark may be ventured that in the Coal Measures, so far as the subject has been worked, there is to be observed the same order of succession of freshwater lamellibranchs which has already been found in the North Staffordshire Coalfield ; and mention may also be made of the apparent absence in South Wales of that fauna, which is so characteristic of the Millstone Grit Series of the Midlands, in rocks which are regarded as their equivalents, and which receive the same name.

Erratic Blocks of the British Isles.—Ninth Report of the Committee, consisting of Dr. J. E. MARR (*Chairman*), Professor P. F. KENDALL (*Secretary*), Professor T. G. BONNEY, Mr. C. E. DE RANCE, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Dr. J. HORNE, Mr. F. M. BURTON, Mr. J. LOMAS, Mr. A. R. DWERRYHOUSE, Mr. J. W. STATHER, Mr. W. T. TUCKER, *and* Mr. F. W. HARMER, *appointed to investigate the Erratic Blocks of the British Isles and to take measures for their preservation.* (*Drawn up by the Secretary.*)

THE most noteworthy records received during the current year are those which are furnished by Mr. J. Lomas from Northamptonshire, Leicestershire, and Rutlandshire, the first and last mentioned counties appearing

for the first time in the reports of the Committee; and the very interesting identifications of the source of certain beach-pebbles found near Cromer in the course of an excursion during the meeting at Cambridge. On this occasion Professor Sjögren and Professor Bäckström, of Stockholm, identified a number of Scandinavian rocks, most of which were well known to glacial workers in Yorkshire, though their place of origin was unknown. These rocks include a cancrinite-syenite from Särna in Dalecarlia, Sweden; quartz porphyry, also from Dalecarlia; a fine-grained granitic rock which is a common and widespread type in Sweden; sparagmite conglomerate from Scania; sparagmite sandstone and a series of hornblende-porphyrites from the Christiania district.

Two pebbles were found, which the present writer identified as trachytes from the south-east of Scotland, a determination which was confirmed by Dr. J. Horne, F.R.S.

The discovery of a fragment of pecten in a gravel-pit at Thirsk, by Mr. J. E. Hall, of that town, is an interesting fact, as no shell-fragments had previously been recorded so far down the vale of York.

Lancashire.

Reported by Mr. J. Lomas, *A.R.C.S.*

On banks of Yarrow River, above Simms's Farm, Anglesark—

Dalbeattie granite, 4 feet by 2 feet 6 inches by 1 foot 2 inches

Winter Hill Stream.—1,120 feet O.D., boulders of Eskdale granite and Lake District andesites.

New Road from Royston Cottage to Belmont.—1,100 feet above O.D. and over.

Kinder Scout grit, very common, one 4 feet 6 inches by 3 feet by 2 feet 6 inches.
Ditto, 5 feet 6 inches by 3 feet 6 inches by 4 feet.
Silurian grit, 1 foot.
Eskdale granite, 1 foot.
Ganister, 2 feet.
Lake District andesite.

Among many hundreds of boulders examined were an enormous number of Carboniferous grits and sandstones, but no Mountain Limestone.

Northamptonshire.

Reported by Mr. J. Lomas, *A.R.C.S.*

Gayton Clay-pit near Blisworth—

Chalky boulder clay, containing Chalk (red and white), Chalk ammonites, flints (white, brown, and red), Bunter pebbles, Great Oolite, Keuper marl.

Hannington (new well in field)—

Chalk, grey flint, Carboniferous grit, Lias limestone, Great Oolite.

Paine's Siding, Glendon, near Kettering—

In Chalky boulder clay many boulders of indurated Northampton Sands, some 3 feet in diameter; Trias pebbles, flints, Lincolnshire Limestone.

Rushton—

Mountain Limestone, with encrinites and brachiopods.
Carboniferous chert, Bunter pebbles, Chalk, and flints.

North of Great Oakley—

Mountain Limestone.

NORTHAMPTON.—*Corby Brickworks.*—Large proportion of Carboniferous boulders, including Mountain Limestone, chert, Millstone Grit, and ganister. Lias limestone, Great Oolite, indurated Northampton Sands, Trias pebbles, and one specimen of mica schist, 3 inches diameter.

Reported by Professor P. F. KENDALL.

Brick-pit near Racecourse (in Chalky boulder clay)—

Spilsby sandstone.

LEICESTERSHIRE.

Reported by Mr. J. LOMAS.

East Norton Railway-cutting—

Carboniferous Limestone.
Millstone Grit.
Carboniferous chert.

Owston Gravel-pit—

Chalk, flints, Lias limestone, Oolite, Bunter pebbles.

Knossington.—Many boulders of Carboniferous limestone and Millstone Grit.

Wymondham.—Old Brickworks near Station—

Mountain Limestone, Chalk, flints, Bunter pebbles.
Oolite, and many Lias limestones.

Coston Bridge—

Coarse dolerite, 3 feet diameter.
Fine-grained dolerite, 1 foot diameter.
Oolite, 2 feet diameter.
Mountain Limestone.

Marl-pit, near Saltby—

Great number of Bunter pebbles, Oolite; no Lias.

Quarry, behind Saltby Church (406 O.D.)—

Lincolnshire Oolite; no Chalk.
Oolitic sandstone.

Wykeham.—Felsitic ash from Charnwood, 2 feet 6 inches diameter. This boulder has been identified by Professor Bonney and is recorded in the Survey Memoir.

Near Grimston—

Mountain Limestone, Millstone Grit, Bunter pebbles, Trias sandstone with concretions of barytes.

Lias limestone; no Oolite. A few pieces of Chalk and flints.

Ragdale—

Many boulders of Mount Sorrel granite, several over 2 feet in diameter. Millstone Grit, Carboniferous sandstone, Lias limestone.

Near Haby—

Millstone Grit, Carboniferous sandstone and chert, Bunter pebbles, and a few flints.

Thrussington Brickyard—

Boulder clay, with Triassic matrix in which bands of selenite have formed.

Numerous boulders of Keuper marl, with plant remains and pseudomorphs of rock salt.

Bunter pebbles (some pitted), Lias limestone, no Oolite, Carboniferous limestone and chert

Aylestone Sand-pit—

Mount Sorrel granite, some with wind-etched surfaces; Carboniferous Limestone and sandstone, Millstone Grit, much Keuper marl with pseudomorphs and plants.

A few Lias limestones and fossils; no Oolite. Coal; no Chalk.

Blaby Clay-pit—

Matrix of clay, almost pure Keuper marl, with bands of gypsum formed in boulder clay.

Numerous Mount Sorrel granite, Carboniferous Limestone, Millstone Grit, Carboniferous sandstone, tea-green marls, Triassic sandstone with barytes. A few Lias fragments; no Oolite.

Enderby Granite-works—

Black Chalky boulder clay with Liassic matrix overlies, red boulder clay with Mountain Limestone, granite and other rocks from the West.

Leicester Forest Brick-works—

Red boulder clay with much Keuper marl, coal, Millstone Grit, Carboniferous sandstone, limestone and chert overlaid by Chalky boulder clay with Liassic matrix, Chalk, flints, and (?) Carboniferous sandstone.

Thurmaston Brickyard—

Red marly boulder clay at base with Carboniferous chert and limestone, Coal Measure sandstone and Millstone Grit, Keuper marls and Triassic sandstone, above Chalky boulder clay with many Liassic limestones and fossils.

RUTLANDSHIRE.

Reported by Mr. J. LOMAS.

Langham, near Oakham (in sewer cutting)—

Middle Lias limestone.

Quarry, near Langham—

Brown boulder clay with dolerite, oolitic limestone, Carboniferous Limestone and chert, Millstone Grit, Trias pebbles and flints.

NORFOLK.

Reported by Professor P. F. KENDALL.

Beach from Cromer to Mundesley—

Rhomb porphyry; laurvikite (two varieties); cancrinite-syenite of Särna, Dalecarlia, Sweden; quartz porphyry, Dalecarlia; fine-grained granite, Sweden; sparagmite sandstone, Scandinavia; sparagmite conglomerate, Scania, Sweden; hornblende-porphyrite, Christiania district, Norway.

YORKSHIRE BOULDER COMMITTEE, 1904.

Reported by Mr. E. HAWKESWORTH.

Brompton and Osmotherley.—Between Brompton and Osmotherley, 3 miles N.E. of Northallerton, in sandy clay exposed in altering road—

Whin Sill, Shap granite, Lake District volcanic series (several varieties), Carboniferous limestones and sandstones numerous, chert.

HULL GEOLOGICAL SOCIETY BOULDER COMMITTEE.

Reported by Mr. G. W. B. MACTURK.

Raywell, near Hull.—In connection with the making of the new reservoir at Raywell an interesting section has been exposed consisting of boulder clay, 10 feet thick, resting on chalk 230 feet O.D. The boulder clay appears to be in two divisions, a red upper clay and a blue or lead-coloured lower clay. Among the erratics the following was recognised :—

Carboniferous Limestone, ganister, porphyrite, greywacke, basalt, &c.

South Cave.—In the field adjoining the railway, 300 yards east of the railway station—

Carboniferous Limestone, Lower Lias.
Soft yellow sandstone, ganister, &c.

Reported by Mr. THOS. SHEPPARD.

Kilnsea, near Spurn—

Two Mammoth teeth.

Reported by Mr. J. E. HALL.

Thirsk.—In the town gravel-pit—

Fragment of *Pecten*.

Photographs of Geological Interest in the United Kingdom.—Fifteenth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor W. W. WATTS (*Secretary*), Professor T. G. BONNEY, Professor E. J. GARWOOD, Professor S. H. REYNOLDS, Dr. TEMPEST ANDERSON, Dr. J. J. H. TEALL, Mr. GODFREY BINGLEY, Mr. H. COATES, Mr. C. V. CROOK, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. W. JEROME HARRISON, Mr. ROBERT KIDSTON, Mr. J. ST. J. PHILLIPS, Mr. A. S. REID, Mr. R. WELCH, Mr. W. WHITAKER, *and* Mr. H. B. WOODWARD. (*Drawn up by the Secretary.*)

THE Committee beg to report that once again the number of new photographs received during the year exceeds that of any previous year. The accessions number 543; the total number in the collection is 4,314, and the yearly average rises to 287. About 100 other photographs have been received, but cannot be added to this year's list.

The geographical scheme annexed shows that four counties are removed from last year's 'black list'—Cambridge, Kildare, Leitrim, and Wicklow having now made contributions to the collection. There are still 21 non-contributing counties—two in England, one in Wales, seven in Scotland, and eleven in Ireland.

To this year's list Yorkshire makes, as so often before, the largest contribution, 243; Norfolk follows with 43, Kent with 31, and Pembroke with 30. Considerable additions are made to the lists of Buckingham, Northampton, Suffolk, Fife, Linlithgow, Renfrew, Cork, and Sligo.

—	Previous Collection	Additions (1904)	Total
ENGLAND—			
Buckinghamshire	8	5	13
Cambridgeshire	—	2	2
Cornwall	57	10	67
Cumberland	43	1	44
Devonshire	178	2	180
Hampshire	36	11	47
Hertfordshire	15	5	20
Kent	81	31	112
Lancashire	69	8	77
Leicestershire	144	4	148
Norfolk	67	43	110
Northamptonshire	6	12	18
Shropshire	54	1	55
Somersetshire	70	8	78
Suffolk	21	24	45
Surrey	54	4	58
Worcestershire	26	1	27
Yorkshire	604	243	847
Others	775	—	775
Total	2,308	415	2,723

—	Previous Collection	Additions (1904)	Total
WALES—			
Anglesey	5	1	6
Carnarvonshire	96	10	106
Pembrokeshire	15	30	45
Others	134	—	134
Total	250	41	291
CHANNEL ISLANDS	38	—	38
ISLE OF MAN	60	1	61
SCOTLAND—			
Edinburgh	47	7	54
Fifeshire	24	19	43
Haddingtonshire	4	1	5
Linlithgow	2	3	5
Renfrewshire	1	4	5
Stirlingshire	15	3	18
Others	329	—	329
Total	422	37	459
IRELAND—			
Antrim	273	5	278
Cork	2	19	21
Down	98	7	105
Dublin	39	3	42
Kildare	—	2	2
Leitrim	—	2	2
Londonderry	23	3	26
Sligo	5	7	12
Wicklow	—	1	1
Others	157	—	157
Total	597	49	646
ROCK STRUCTURES, &c.	96	—	96
SUMMARY.			
ENGLAND	2,308	415	2,723
WALES	250	41	291
CHANNEL ISLANDS	38	—	38
ISLE OF MAN	60	1	61
SCOTLAND	422	37	459
IRELAND	597	49	646
ROCK STRUCTURES, &c.	96	—	96
Total	3,771	543	4,314

It is not easy to pick out any particular series of photographs for special mention, but a set of seventeen prints from Mr. Charles C. Buckingham, and two from Mr. De Vere, all taken under the auspices of the East Kent Natural History Society, seem to be of exceptional interest. They illustrate the course and tributaries of the Kentish river Stour, and their

association with the springs known as Bournes. Mr. Buckingham has also photographed Reculvers Church from the same points of view as Lyell's famous pictures, and the result brings home the potency of marine denudation and the need for coast defences.

Mr. R. Vowell Sherring, working in conjunction with the Bournemouth and District Society of Natural Science, sends some beautiful prints of the Bournemouth cliffs; Mr. Mellard Reade contributes some excellent photographs of the well-known gypsum boulder of Crosby; and Mr. Topham a series from the gravels of Eye in Northamptonshire. The rhythmical fretting of limestone by water in Hell Gill is illustrated by Mr. Rodwell under circumstances of considerable difficulty, and the marine destruction of the Scarborough landslips by Mr. Monckton. Mr. Leach sends photographs of a mass of Carboniferous Limestone at Tenby, supposed to show 10,000 specimens of *Productus*, and, curiously enough, almost the same post brought a notice that 'the Corporation have for years been breaking up the stone for road repair, and are now in possession of a steam stone-breaker which will in the course of time cause this natural curiosity to disappear, unless some steps are taken to prevent it.'

Messrs. Muff and Wright have taken an ideal set of photographs of the raised beaches and platforms of Cork, which are buried under boulder-clay, blown-sand, and 'head;' Mr. Pledge continues to illustrate Mr. Davies's work on the Purbeck and Portland of the Haddenham district; Mr. Robarts sends further contributions on the geology of Kent and Surrey from the Croydon Natural History and Scientific Society; and Mr. Plews gives the first photographs recorded from Cambridgeshire.

The importance of the contributions of members of the Committee will be realised from the fact that they are responsible for 426 photographs out of a total of 541. Mr. W. Jerome Harrison, one of the earliest and most earnest of geological photographers, and perhaps the pioneer of county photographic surveys, sends no less than 270 prints out of his large collection of a lifetime. These comprise a large series of the Yorkshire coast from Bridlington to Whitby, series from Cornwall, Norfolk, and Suffolk, and our first connected set from the Cambrian rocks of St. Davids. Mr. Bingley contributes 76 prints taken in Norfolk, Suffolk, Yorkshire, Anglesey, and Carnarvon. Professor Reynolds's work is well represented by illustrations from Hertfordshire, the Carboniferous area of Somerset, and volcanic areas in Fife, Haddington, and Linlithgow. Last, but not least, Mr. Welch makes a valuable gift of 35 prints taken in Lancashire and Ireland, in connection with the work of the Belfast Naturalists' Field Club, and of Mr. Praeger and Mr. Lamplugh. These include examples from Antrim and Cork, the glacial and associated deposits of Down and Dublin, and phenomena connected with limestones and caves in Sligo. One of the photographs is both botanical and geological, for it shows the formation of tufa in a limestone-district through the agency of colonies of various mosses.

To all the gentlemen named the Committee tender their best thanks, as well as to the following, who have contributed less in amount, it is true, but individual examples or series of high value: Mr. Epps, Mr. G. T. Atchison, Mr. Hopkinson, Messrs. Abley and Griffith, Mr. Hodson,

Professor Armstrong, Mr. Cobbold, Dr. Matley, Dr. Flett, Dr. Abbott, and Mr. Smith.

Mr. Welch points out that one print registered last year (3289), the cemented breccia of quartzite and slate at Howth, which contained bones of mammals and fishes with land and marine shells, is now the only record of an interesting geological fact, as the block has been washed away by the sea.

The third and last issue of the published series of 'British Geological Photographs' was sent out to subscribers in May of this year. The completion and success of its first publication scheme marks an epoch in the history of the Committee and the fulfilment of a long-cherished desire of its founders.

Since the first meeting in 1890 the desirability of publishing a selected series of geological photographs has been kept before the Committee, but it was only in 1893 and 1894 that publishers were approached on the subject. With one consent they recommended us to go elsewhere, and so the matter was allowed to slumber till the Dover meeting in 1899. In that year a Sub-Committee of selection, consisting of Professor Bonney (Chairman), Professor Watts (Secretary and Editor), Professor Garwood, Dr. Mill, Dr. Teall, and Mr. H. B. Woodward, was appointed, a self-supporting subscription scheme drawn up, and a preliminary selection of typical photographs made. One hundred and ninety-three subscribers undertook to support a series which was to consist of issues of twenty photographs each year for three years. It was decided to issue the series in three forms—unmounted half-plate platinotypes, mounted platinotypes, and lantern slides—and each issue was to be accompanied by descriptive letterpress.

Various unforeseen circumstances delayed the first issue, but it saw the light in September 1902; issue ii. followed in July 1903, and the final issue in May 1904. The actual series, as published, comprised seventy-two photographs, fifty-one being standard half-plates, ten quarter-plates, and eleven whole-plates, and an equal number of lantern slides. The subjects ranged over most of the ordinary geological phenomena, the chief rock formations, and many of the more important British localities. The negatives were lent by thirty-four photographers, and a descriptive pamphlet of forty-two pages was written by thirty-four contributors, amongst whom are many of the most famous of contemporary British geologists. To both geologists and photographers the Committee express their warmest thanks.

The estimates on which the Sub-Committee worked proved to have been well founded, and the annexed balance-sheet gives an account of all receipts and expenditure to date. It shows a balance in favour of the Committee of £95 13*s.* 2*d.*, and a prospective profit of over £130 when all outstanding accounts shall have been paid.

The balance-sheet, however, does not make one important point clear. Eight whole-plate platinotypes and twelve slides beyond the number agreed upon have been issued to subscribers. It is estimated that these additional photographs have cost £105. If this be added to the balance in hand the total profit has been £235, of which one-half has been returned to the subscribers and the other half retained by the Committee for the purpose of carrying on the work for which it was originally established by the Association.

Balance-sheet, Publication Account, to August 13, 1904.

RECEIPTS.	£	s.	d.
Prints only	148	1	0
Mounted prints	196	10	0
Slides	251	5	0
Prints and slides	80	10	0
Mounts and slides	126	10	0
Mounts and prints	7	13	0
Prints, mounts and slides	11	8	0
	821	17	0
Less arrears unpaid	40	19	0
Total	780	18	0

PAYMENTS.	£	s.	d.
Preliminary expenses and apparatus	24	9	6
Copying negatives	21	7	5
Copyright and purchase	6	19	0
Prints	224	1	4
Mounts and mounting	36	8	0
Albums and boxes	13	4	2
Slides and mounting	176	0	1
Packing	16	2	1
Carriage of parcels	29	10	0
Printing and stationery	55	7	0
Office expenses	7	6	$4\frac{1}{2}$
Postage	13	7	$0\frac{1}{2}$
Renewing broken slides	11	0	7
Sets for new subscribers	27	12	4
Interest on working capital	17	10	0
Exhibition expenses (St. Louis and London)	4	19	11
Balance transferred to Committee's account (£136 12*s.* 2*d.*, less unpaid £40 19*s.*)	95	13	2
Total	780	18	0

It was pointed out in the Report for last year that in its fourteen years' work of collecting and storing photographs, the Committee had spent £101 10*s.* of the £130 granted to it by the Association. In making a clear profit of £130 the Committee may congratulate itself on having 'earned its keep,' and perhaps it is the only Committee of the Association which has ever succeeded in literally doing so. But, besides this, by scattering broadcast over the world typical photographs of geological features and phenomena it has rendered a service to geological, and perhaps to geographical, teaching which cannot be well over-estimated. The British Association photographs are forming the nucleus of dozens of teaching-collections in the universities, schools, and museums of Britain; and numerous foreign subscribers write that they are only unable to subscribe to a second series because they now want the funds to accumulate other examples from their own countries. It is not so difficult to obtain geological photographs as it was fifteen years ago, for even the ubiquitous picture post card is sometimes frankly geological.

At a meeting of the Committee held in Cambridge on August 19, 1904, Dr. J. J. H. Teall, F.R.S., in the chair, it was unanimously agreed That this Committee desires to record its admiration of the indefatigable energy shown by its Secretary, both in carrying out the original aims of the Committee and in bringing to a successful issue the publication

of a typical series of Geological Photographs, services to Geological Science which cannot well be overestimated.'

About 100 intending subscribers to a new series have sent in their names, and the Committee recommend that such a new series be undertaken on the same terms as the last. With the smaller number of subscribers, however, the margin is narrow, and while profit to the Committee will be small, or absent, the subscribers will have to be content with the 'contract number' of photographs. Possibly the number of subscribers will increase when it is known that the new series will be actually carried out.

Such a series will naturally be complete in itself, but it will also be supplementary to the first series, and in no way a repetition of it. The Committee would most warmly welcome any suggestions from subscribers and others as to the best points to be considered in the new series.

Examples of the published series of photographs were shown at the Exhibition arranged by the Geographical Association in London and the provinces this year. Another set was sent by request to the Exhibition at St. Louis, and it is proposed to present this collection to the Geographical and Geological Department at Harvard University when the exhibition closes. To this set a gold medal has been awarded in group 16.

The duplicate collection of slides has been exhibited and explained within the year by Mr. Whitaker at the following local scientific societies :—The Christ's Hospital Natural History Society, the Greville Place Literary Society, Maida Vale, the Stratford Congregational Literary Society, and the Ashmolean Natural History Society, Oxford.

Applications by Local Societies for the loan of the duplicate collection should be made to the Secretary. Either prints or slides, or both, can be lent, with a descriptive account of the slides. The carriage and the making good of any damage to slides or prints are expenses borne by the borrowing society.

The Committee recommend that they be reappointed without a grant.

FIFTEENTH LIST OF GEOLOGICAL PHOTOGRAPHS.

AUGUST 17, 1903, TO AUGUST 12, 1904.

This list includes the geological photographs which have been received by the Secretary of the Committee since the publication of the last report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers are added in order to enable them to do so.

Copies of photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the local society under whose auspices the views were taken.

The price at which copies may be obtained depends on the size of the print and on local circumstances over which the Committee have no control.

The Committee *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

It is recommended that, wherever the negative is suitable, the print be made by the cold-bath platinotype process. The very best photographs lose half their utility, and all their value as documentary evidence, unless accurately described; and the Secretary would be grateful if, whenever

possible, such explanatory details as can be given were written on the forms supplied by him for the purpose, and *not on the back of the photograph or elsewhere.* Much labour and error of transcription would thereby be saved. It is well, also, to use a permanent ink for this purpose. A local number, by which the print and negative can be recognised, should be written on the back of the photograph and on the top right-hand corner of the form.

Copies of photographs should be sent *unmounted* to W. W. Watts, The University, Birmingham, and forms may be obtained from him.

The size of photographs is indicated as follows :—

L = Lantern size.	1/1 = Whole-plate.
1/4 = Quarter-plate.	10/8 = 10 inches by 8.
1/2 = Half-plate.	12/10 = 12 inches by 10, &c.

E signifies Enlargements.

* Indicates that photographs and slides may be purchased from the donors, or obtained through the address given with the series.

LIST I.

ACCESSIONS IN 1903–1904.

ENGLAND.

BUCKINGHAMSHIRE.—*Photographed by* J. H. PLEDGE, 115 *Richmond Road, Dalston, N.E.* 1/2.

Regd. No.		
4296	(B 14) Cutting near Digg's Farm, Haddenham.	Upper Portland and Purbeck. 1903.
3756	(B 15) Cutting N.W. of Haddenham to Thame Road.	River Gravel. 1903.
3757	(B 16) Cutting S. of main road, Thame to Aylesbury, Haddenham.	Portlandian Pebble-bed. 1903.
3758	(B 17) Cutting S. of main road, Thame to Aylesbury, Haddenham.	Portland Beds. 1903.
3759	(B 18) Cutting S. of main road, Thame to Aylesbury, Haddenham.	Pebble Bed in Portland. 1903.

CAMBRIDGE.—*Photographed by* A. G. PLEWS, *Pembroke College, Cambridge.* 1/4.

3760	( ) Brick Pit at Gamlingay .	Unconformity of Lower Greensand on Ampthill Clay. 1903.
3761	( ) ,, ,, .	Unconformity of Lower Greensand on Ampthill Clay. 1903.

CORNWALL.—*Photographed by* W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 7/5.

3762	(408) Cliffs N. of Newquay	Devonian Rocks. 1894.
3763	(1097 F) ,, ,,	Coast erosion. ,,
3764	(420) Walrus Rock, N. of Newquay.	,, ,

Regd. No.			
3765	(1109 F) The Porth, Newquay		1894
3766	(1106 F) „ „	'The Norwegian.'	
3767	(1105 F) N. side of the Porth, Newquay.	Rock chasm.	„
3768	(1099 F) 3 miles N. of Newquay	Folded rocks	„
3769	(1528 F) Cliffs 3 to 5 miles N. of Newquay.		„
3770	(1096 F) Bedruthan Steps . .		„
3771	(1116 F) Bedruthan . . .		„

Cumberland.—*Photographed by* G. T. Atchison, *M.A., LL.B., Holmwood, Sutton Coldfield.* 1/2

4297	(67) Below Watendlath, Borrowdale.	'The Devil's Punchbowl.' 1902.

Devonshire.—*Photographed by* C. H. B. Epps, *B.A.*, 95 *Upper Tulse Hill, S.W.* 5/4.

3772	(1150) Bathing Beach, Ilfracombe.	Isoclinal fold in slate. 1903.
3773	(1151) Bathing Beach, Ilfracombe.	Strain-slip cleavage on large scale. 1903.

Hampshire (Isle of Wight).—*Photographed by* J. Hopkinson, *F.G.S., Weetwood, Watford.* 1/4.

3774	(14) Undercliff between St. Lawrence and Ventnor.	Bands of Chert in Upper Greensand. 1903.
3775	(15) Undercliff between St. Lawrence and Ventnor.	Bands of Chert in Upper Greensand. 1903.

Photographed by R. Vowell Sherring, *F.L.S., Hallatrow, near Bristol. Bournemouth and District Society of Natural Science.* 10/8.

4256	(1) Cliffs W. of Gordon Hotel Steps, Southbourne, Bournemouth.	Eocene Beds. 1904.
4257	(2) E. of Gordon Hotel Steps, Southbourne, Bournemouth.	Lignite Bed above high-water mark. 1904.
4258	(3) E. of Gordon Hotel Steps, Southbourne, Bournemouth.	Leaf Bed *in situ.* 1904.
4259	(4) Southbourne Cliffs, Bournemouth.	Silver-sand Bed and cliff erosion. 1904.
4260	(5) Southbourne Cliffs, Bournemouth.	„ „ „ „
4261	(6) Southbourne Cliffs, Bournemouth.	Cliff erosion. 1904.
4262	(7) Southbourne Cliffs, Bournemouth.	Sands and clays. 1904.

Photographed by W. E. Abley, *Kingsgate Street, Winchester.* 1/1.

4264	(320) Three miles from Winchester, on road to Petersfield.	Broad, flat floor of Chalk combe and dry watercourses at its head. 1903.
4265	(321) Three miles from Winchester, on road to Petersfield.	Narrow valley in continuation of combe. 1903.

HERTFORDSHIRE.—*Photographed by* J. HOPKINSON, *F.G.S., Weetwood, Watford.* 1/4.

Regd. No.		
3776	(16) Lane to Bottom Farm, Valley of the Bourne.	Lane converted into river from December 1903 to May 1904. 1904.
3777	(17) Gravel-pit in Bourne Valley	Converted into pond from December 1903 to June 1904. 1904.

Photographed by Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

3778	(A 14) Railway Cutting, Chorley Wood.	Pipes and pockets of Gravel in Chalk. 1903.
3779	(A 15) Railway Cutting, Chorley Wood.	Pipes and pockets of Gravel in Chalk. 1903.
3780	(A 16) Railway Cutting, Chorley Wood.	Pipes and pockets of Gravel in Chalk. 1903.

KENT.—*Photographed by* N. F. ROBARTS, *F.G.S.*, 23 *Oliver Grove, South Norwood, S.E.* 1/4.

3781	(28) Oldbury Hill, Ightham .	Sandpit in Folkestone Beds. 1904.

KENT.—*Photographed by* CHARLES C. BUCKINGHAM, 13 *York Road, Canterbury.* 1/4 *and* 1/2.

4266	(100) S.E. of Lenham . .	Source of Great Stour. 1902.
4267	(101) „ . .	„ „ „
4268	(102) „ . .	Stream from spring at head of Great Stour. 1902.
4269	(103) „ . .	Lake formed where two sources of Great Stour meet. 1902.
4270	(104) „ . .	Great Stour leaving Lake. 1902.
4271	(105) Milton, near Canterbury .	River Stour altering its course. 1902.
4272	(106) Marsh side . . .	Bed of ancient Wantsum. 1902.
4273	(107) Postling	Source of East Stour. 1902.
4274	(108) Etchen Hill . . .	Spring at head of Elham Nailbourne. 1903.
4277	(111) Kingstone . . .	Course of Lesser Stour. 1903.
4278	(112) Patrixbourne . . .	„ „ „
4279	(113) Bekesbourne . . .	„ „ „
4280	(114) „ . . .	„ „ „
4281	(115) Near Bekesbourne . .	Springs on course of Lesser Stour. 1903.
4282	(116) „ . .	Stream from springs (4281). 1903.
4283	(117) Wickhambreaux . .	Lesser Stour banked up for power purposes. 1903.
4284	(118) „ . .	Lesser Stour at Seaton Mill. 1903.
4285	(119) Reculvers at high water	From point of view of Lyell's 'Principles,' fig. 53. 1903.
4286	(120) „ „ .	From point of view of Lyell's 'Principles,' fig. 54. 1903.
4287	(121) Between Reculvers and Herne Bay.	Thanet Sands and Woolwich Beds. 1903.
4288	(122) Between Reculvers and Herne Bay.	„ „ „
4289	(123) Between Reculvers and Herne Bay.	Woolwich and Oldhaven Beds. 1903.

Regd. No.		
4290	(124) Between Reculvers and Herne Bay.	Woolwich and Oldhaven Beds. 1903.
4291	(125) Between Reculvers and Herne Bay.	Oldhaven Gap. 1903.
4292	(126) Between Reculvers and Herne Bay.	Woolwich and Oldhaven Beds and London Clay. 1903.
4293	(127) Between Reculvers and Herne Bay.	London Clay crumbling over Oldhaven Beds. 1903.
4294	(128) Between Reculvers and Herne Bay.	London Clay. 1903.
4295	(129) Between Reculvers and Herne Bay.	" " "

Photographed by T. De Vere, *Belle Vue, Harbledown, Canterbury.* 1/4.

4275	(109) Lyminge	Springs at head of Elham Nailbourne. 1903.
4276	(110) Derringstone . . .	Course of Lesser Stour, now being used as a road. 1903.

Lancashire.—**Photographed by* R. Welch, *Lonsdale Street, Belfast.* 1/1.

3782	(4102) Bispham Cliffs, Blackpool.	False-bedding in Glacial Sands and Gravels. 1903.
3783	(4105) Bispham Cliffs, Blackpool.	Cemented Glacial Sands and Gravel fallen on beach. 1903.
3784	(4103) Bispham Cliffs, Blackpool.	Cemented Glacial Sands and Gravel forming sea-stacks. 1903.
3785	(4104) Bispham Cliffs, Blackpool.	Fallen masses of Glacial Sands and Gravels. 1903.

**Photographed by* Messrs. Hartley Brothers, *South Road, Waterloo, and Presented by* T. Mellard Reade, *F.G.S.* 1/1.

3786	( ) Great Crosby . . .	Gypsum boulder, 18 tons. 1898.
3787	( ) " . . .	" " "
3788	( ) " . . .	" " "
3789	( ) " . . .	" " "

Leicestershire.—*Photographed by* A. G. Plews, *Pembroke College, Cambridge.* 1/4.

3790	( ) Charnwood Lodge Drive	Cleaved Volcanic Agglomerate. 1903.

Photographed by Professor H. E. Armstrong, *F.R.S.*, 55 *Granville Park, Lewisham.* 1/2.

3755	( ) Mountsorrel, Leicester .	Terraced Granite surface under Keuper Marl. 1903.

Photographed by G. Hodson, *M.Inst.C.E., Loughborough.* 1/1 *and* 1/4.

3791	( ) One Barrow Quarry, Charnwood.	Grit in Blackbrook Series. 1904.
3792	( ) Blackbrook, near Shepshed.	Masonry dam for reservoir. 1903 ?

NORFOLK.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Regd. No.		
3793	(6143) Happisburgh . .	Lower Till. 1903.
3794	(6144) „ . . .	Laminated Beds in Lower Till. 1903.
3795	(6145) Cliffs, Happisburgh .	Lower and Upper Till. 1903.
3796	(6146) Cliff 20 yards N. of Old Kiln, Ostend, near Happisburgh.	Contorted Beds resting on Till. 1903.
3797	(6147) Cliffs, near Bacton Gap .	Till, Contorted Drift, and River Gravel. 1903.
3798	(6148) Cliffs to N. of Bacton Gap.	Till, Contorted Drift, and River Gravel 1903.
3799	(6149) Cliffs between Bacton and Mundesley.	Contorted Drift. 1903.
3800	(6151) Cliffs between Bacton and Mundesley.	„ „
3801	(6152) Cliffs N. of Mundesley .	Contorted Till. „
3802	(6153) „ „ .	„ „
3803	(6163) Cliffs, East Runton, near Cromer.	Gravel Bed. „
3804	(6160) Runton, near Cromer .	'Forest Bed.' „
3805	(6161) „ „ .	Mass of Chalk in Contorted Drift. 1903.
3806	(6162) „ „ .	Masses of Chalk in Contorted Drift. „
3807	(6159) Cliffs, Beeston, near Sheringham.	Erratic of Chalk Marl. 1903.
3808	(6157) Cliffs near Sheringham .	Weybourne Crag on Chalk. 1903.
3809	(6158) „ „	Contorted Drift. 1903.
3810	(6155) Cliffs, Weybourne . .	Crag on disturbed Chalk. 1903.
3811	(6156) Cliffs S. of Weybourne .	„ „ „
3812	(6164) Sprowston Road, Norwich	Chalk Pit. 1903.
3813	(6165) Watling's Pit, Sprowston, Norwich.	Glacial Sands and Gravels on Brick-earth. 1903.
3814	(6166) Watling's Pit, Sprowston, Norwich.	Glacial Sands and Gravels on Brick-earth. 1903.
3815	(6167) Hellesdon, Norwich .	Chalky Boulder Clay with irregular decalcification. 1903.
3816	(6168) Mousehold Heath, Norwich.	'Cannon-shot' Gravel. 1903.
3817	(6169) Plumstead Road, Norwich.	'Cannon-shot' Gravel on Contorted Glacial Sands. 1903.
3818	(6171) Thorpe Crag Pit, Norwich.	Chalk and Norwich Crag. 1903.
3819	(6172) Thorpe Crag Pit, Norwich.	„ „ „
3820	(6173) Woodlands Lane Quarry, Norwich.	Lower Glacial Sand covered with Boulder Clay. 1903.
3821	(6182) Forncett . . .	Chalky Boulder Clay, with piece of Kimmeridge Clay. 1903.
3822	(6183) „ . . .	Chalky Boulder Clay, with piece of Kimmeridge Clay. 1903.
3823	(6184) Tharston Furze Hill .	Chalk, Crag, Westleton Beds, and Gravel. 1903.
3824	(6185) „ „ .	Chalk, Crag, Westleton Beds, and Gravel. 1903.

Photographed by W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 7/5.

Regd. No.			
3825	(1826 F)	Cliffs W. of Cromer .	Large Boulder of Chalk embedded in Drift. 1896.
3826	(1836 F)	„ „ .	Contorted Drift. 1896.
3827	(1835 F)	Runton Gap, near Cromer.	Sandy Drift. „
3828	(1873 F)	Cliffs at Beeston, near Sheringham.	Contorted Drift. „
3829	(1890 F)	Beeston Cliffs . .	„ „
3830	(1832 F)	E. of Sheringham .	„ „
3831	(1891 F)	Sheringham Beach .	Sea Defences „
3832	(1831 F)	W. of Sheringham .	Pinnacle of Chalk in Drift. 1896.
3833	(497)	Cliff-end at Weybourne	Chalk and Crag. 1896.

Photographed by E. CORDER, *and Presented by* T. SOUTHWELL, *The Crescent, Norwich.* 1/4.

3834	( )	Sidestrand Church . .	Landslip. 1896.

Photographed by J. CARVER, *Unthank Road, Norwich.* 1/4.

3835	( )	Sidestrand Church . .	Landslip. 1896.

NORTHAMPTONSHIRE.—*Photographed by* C. H. TOPHAM, 110 *York Road, Montpelier, Bristol.*

3836	(1)	Eye	False-bedded Gravel. 1896.
3837	(2)	„	Current-bedded Sand and Gravel. 1896.
3838	(3)	„	False-bedded Sand and Gravel. 1896
3839	(4)	„	Coarse false-bedded Gravel. 1896.
3840	(5)	„	Lenticular false-bedded Sand and Gravel. 1896.
3841	(6)	„	Sand-bed in Gravel. 1896.
3842	(7)	„	Deposition of Sand against Gravel ridges. 1896.
3843	(8)	„	False anticlines owing to deposition. 1896.
3844	(9)	„	High-angle false-bedding. 1896.
3845	(10)	„	Low angle false-bedding. 1896.
3846	(11)	„	Filled fissure and fault in Gravel. 1896.
3847	(12)	„	Fissure in Gravel. 1896.

SHROPSHIRE.—*Photographed by* E. S. COBBOLD, *F.G.S., Watling House, Church Stretton.* 1/4.

3848	( )	Belswardine Brook, Shineton.	Unconformity of Upper Llandovery Sandstone on Shineton Shales. 1903.

SOMERSET.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/2.

3849	(A 5)	Middle Hope, Weston-super-Mare.	Volcanic Rocks in Carboniferous Limestone. 1903.
3850	(A 6)	Middle Hope, Weston-super-Mare.	Bedded Calcareous Tuffs. 1903.

Regd. No.		
3851	(A 7) Middle Hope, Weston-super-Mare.	Tuffs and Limestone with Calcite veining. 1904.
3852	(A 8) Spring Cove, near Weston	Basalt Flow in Carboniferous Limestone. 1904.
3853	(A 9) Spring Cove, near Weston	Basalt Flow in Carboniferous Limestone. 1904.
3854	(A 10) Spring Cove, near Weston	Basalt Flow in Carboniferous Limestone. 1904.
3855	(A 12) South side of Cheddar Gorge.	Weathering along joints. 1904.
3856	(A 13) Cheddar Gorge . .	Carboniferous Limestone. 1903.

SUFFOLK.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

3857	(6178) Cliffs near Kessingland	Current-bedding in Glacial Sands and Gravels. 1903.
3858	(6175) Cliffs between Kessingland and Lowestoft.	Chalky Boulder Clay, and Glacial Sands and Gravels. 1903.
3859	(6176) Cliffs between Kessingland and Lowestoft.	Chalky Boulder Clay, and Glacial Sands and Gravels. 1903.
3860	(6177) Cliffs between Kessingland and Lowestoft.	Chalky Boulder Clay, Glacial Sands, and 'Forest bed.' 1903.
3861	(6174) Pakefield Clay Pit, near Lowestoft.	Chalky Boulder Clay on Glacial Sands. 1903.
3862	(6179) South of Lowestoft .	Pebble beach. 1903.
3863	(6181) Cliffs, Corton, N. of Lowestoft.	Chalky Boulder Clay, Sands and Gravels, and Brick-earth. 1903.

Photographed by W. JEROME HARRISON, *F.G.S.*, 52 *Claremont Road, Handsworth, Birmingham.* 1/2.

3864	(273) Cliffs N. of Southwold .	Orange-coloured Sands. 1901.
3865	(274) " " " .	Orange and White Sands. 1901.
3866	(275) " " " .	Pebble bed. 1901.
3867	(276) " " " .	Sands and Laminated Clays. 1901.
3868	(280) " " " .	Westleton Beds resting on Laminated Clays. 1901.
3869	(282) " " " .	'Crag' with shells near base. 1901.
3870	(277) " " " .	"
3871	(278) " " " .	"
3872	(279) " " " .	"
3873	(281) " " " .	"
3874	(283) " " " .	"
3875	(284) " " " .	"
3876	(292) Cliffs ¼ mile S. of League Hole, S. of Gorleston.	Glacial Sands and 'Forest Bed.' "
3877	(294) Cliffs ¼ mile S. of League Hole, S. of Gorleston.	Glacial Sands on Loam. 1901.
3878	(293) ¼ mile N. of League Hole	Glacial Sands. "
3879	(295) 1 mile S. of Gorleston .	Mid-glacial Sands. 1901.
3880	(296) 1 mile S. of Gorleston .	" " "

SURREY.—*Photographed by* N. F. ROBARTS, *F.G.S.*, 23 *Oliver Grove, South Norwood, S.E.* 1/4.

3881	(21) Box Hill from Norbury Park.	Chalk escarpment. 1904.
3882	(25) Worms Heath Gravel Pit .	Pipe of Clay in Oldhaven Pebble Beds. 1904.

Regd. No.		
3883	(26) Worms Heath Gravel Pit .	Pipe of Clay in Oldhaven Pebble Beds. 1904.
3884	(27) Bughill Farm, Woldingham	Outbreak of Croydon Bourne. 1904.

WORCESTERSHIRE.—*Photographed by* C. A. MATLEY, *D.Sc., F.G.S., 90 St. Lawrence Road, Clontarf, Dublin.* 1/4.

3885	(10) Wren's Nest Hill, Dudley .	Quarries and pillars in Wenlock Limestone. 1901.

YORKSHIRE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

3886	(6356) Spurn Head . . .	Looking N. from Lighthouse. 1904.
3887	(6358) „ „ . . .	Looking S.W. from Lighthouse. „
3888	(6382) Cliffs N. of Kilnsea Beacon.	„
3889	(6383) Cliffs near Kilnsea Beacon.	„
3890	(6378) Near Easington . .	Looking towards Kilnsea Beacon. 1904.
3891	(6381) Cliffs N. of Easington .	Slipped and wasting cliff. 1904.
3892	(6368) Out Newton, near Withernsea.	Purple Boulder Clay and Glacial Gravels. 1904.
3893	(6369) Out Newton, near Withernsea.	Purple Boulder Clay and Glacial Gravels. 1904.
3894	(6370) Out Newton, near Withernsea.	Purple Boulder Clay with slipped masses. 1904.
3895	(6371) Out Newton, near Withernsea.	Hessle, Purple, Laminated, and Basement Clays.
3896	(6372) Dimlington Cliffs . .	Coast erosion. 1904.
3897	(6373) „ „ . .	Basement and Purple Clays. 1904.
3898	(6374) „ „ . .	Hessle, Purple, Laminated and Basement Clays. 1904.
3899	(6375) „ „ . .	Basement and Purple Clays. 1904.
3900	(6379) „ „ . .	Shelly Basement Clay capped with Purple Clay. 1904.
3901	(6380) „ „ . .	Spring in cliff. 1904.
3902	(6296) Scarborough, Marine Drive.	Fossiliferous Calcareous Grit. 1903.
3903	(6322) Penny Farm Gill, near Sedbergh.	Vertical Carboniferous Limestone. 1904.
3904	(6324) Penny Farm Gill, near Sedbergh.	„ „ „
3905	(6237) Helm Gill, Dent Dale .	Lamprophyre Dyke in Coniston Limestone. 1904.
3906	(6316) River Clough, Garsdale, near Sedbergh.	Carboniferous Conglomerate. 1904.
3907	(6319) Hebblethwaite Gill, Sedbergh.	„ „ „
3908	(6232) Ganister Quarry, Meanwood Valley, Leeds.	Overthrust Fault. 1903.
3909	(6260) Ganister Quarry, Meanwood Valley, Leeds.	Folded Coal and Ganister. 1904.
3910	(6262) Ganister Quarry, Meanwood Valley, Leeds.	„ „ „
3911	(6259) Ganister Quarry, Meanwood Valley, Leeds.	„ „ „

Photographed by J. H. RODWELL, *Brooklyn Villa, New Manston, near Leeds.* 1/2.

Regd. No.		
3912	( ) Hell Gill, Mallerstang.	Fretting of Limestone by water.

Photographed by LOUIS SMITH, *Conisborough.* 1/2.

3913	(251) Conisborough . . .	Undercut and weathered block of Magnesian Limestone.

Photographed by W. JEROME HARRISON, *F.G.S.*, 52 *Claremont Road, Handsworth, Birmingham.* 1/2, 7/5, *and* 1/1.

3914	(310 F) Balby Sandpit, near Doncaster.	Bunter capped by Gravels. 1903.
3915	(311 F) Balby Sandpit, near Doncaster.	Bunter Sandstone. 1903.
3916	(312 F) Balby Sandpit, near Doncaster.	Bunter capped by Gravels. 1903.
3917	(313 F) Balby Sandpit, near Doncaster.	Bunter. 1903.
3918	(314 F) Warmsworth, near Doncaster.	Quarry in Magnesian Limestone. 1903.
3919	(315 F) Warmsworth, near Doncaster.	,, ,, ,,
3920	(322 F) Adel Crags, near Leeds.	Millstone Grit. 1903.
3921	(476) Ackworth . . .	Grindstone Quarries in Coal-measures. 1903.
3922	(292 F) Brimham Rocks, Pateley Bridge.	Wind erosion of Millstone Grit. 1903.
3923	(293 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3924	(294 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3925	(296 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3926	(297 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3927	(299 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3928	(300 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3929	(301 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3930	(302 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3931	(303 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3932	(304 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3933	(306 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3934	(307 F) Brimham Rocks, Pateley Bridge.	,, ,, ,, ,,
3935	(373 F) Hilderthorpe, S. of Bridlington.	Boulder Clay and Contorted Sands. 1898.
3936	(590) Hilderthorpe, S. of Bridlington.	,, ,, ,, ,,

Regd. No.		
3937	(592) Hilderthorpe, S. of Bridlington.	Boulder Clay and Contorted Sands. 1898.
3938	(593) Hilderthorpe, S. of Bridlington.	Boulder Clay under Laminated Loam. "
3939	(2079 F) Hilderthorpe, S. of Bridlington.	Drift. 1898.
3940	(885) Flamborough from near Danes Dyke.	Chalk and Drift. 1898.
3941	(387) Flamborough Head S.W. of Danes Dyke.	Chalk capped by Drift. 1898.
3942	(370 F) High Stacks, Flamborough.	" " "
3943	(371 F) High Stacks, Flamborough.	Drift-filled river channel. "
3944	(372 F) High Stacks, Flamborough.	Chalk and Drift. "
3945	(382 F) Flamborough Head, near High Stacks.	Sea Caves in Chalk. "
3946	(2067 F) Flamborough Head .	Chalk and Boulder Clay. "
3947	(901) Flamborough Head, N. side.	" " "
3948	(367 F) Selwick Bay, Flamborough.	" " "
3949	(369 F) Selwick Bay, Flamborough.	" " "
3950	(365 F) Selwick Bay, Flamborough.	'Adam Rock.' 1898.
3951	(366 F) Selwick Bay, Flamborough.	'Eve Rock.' 1898.
3952	(384 F) Near Breil Point, Flamborough.	'King and Queen Rocks.' 1898.
3953	(899) Near Breil Point, Flamborough.	" " "
3954	(891) North Sea Landing, Flamborough.	Chalk and Drift, Caves. "
3955	(2066 F) North Sea Landing, Flamborough.	" " "
3956	(895) North Sea Landing, Flamborough.	Caves in Chalk. 1898.
3957	(892) North Sea Landing, W. side.	Chalk Caves and Drift Plateau. 1898.
3958	(896) North Sea Landing .	Entrance to Church Cave. "
3959	(385 F) " " .	"
3960	(2068 F) Ravine W. of North Sea Landing.	"
3961	(2076 F) Thornwick Bay, E. side.	Chalk and Drift. 1898.
3962	(2075 F) " " .	" " "
3963	(2073 F) Thornwick Bay . .	" " "
3964	(2069 F) " " . .	" " "
3965	(2061 F) Speeton Gap .	" " "
3966	(2064 F) Speeton Cliffs N. of Gap	Drift. 1898.
3967	(2060 F) Speeton . . .	Moraine, from Windmill. 1898.
3968	(2059 F) " . . .	" " "
3969	(2065 F) Filey, Cliffs S. of .	Drift. 1898.
3970	(451) Filey, Cliffs and Brigg .	Boulder Clay. 1902.
3971	(227) Carr Naze, Filey . .	Boulder Clay on Corallian Rocks. 1902.
3972	(228) " " . .	" " " "
3973	(233) " " . .	" " " "
3974	(226) " " . .	" " " "
3975	(230) " " . .	" " " "
3976	(224) Filey Brigg . . .	Calcareous Grit. 1902.
3977	(231) Filey Brigg and Cliffs .	Corallian Rocks under Boulder Clay. 1902.

Regd. No.		
3978	(225) Filey, N. of Brigg .	. Corallian Rocks. 1902.
3979	(232) Filey Brigg and Cliffs	. " " "
3980	(449) Gristhorpe Bay, S. of	. Oxford Clay and Corallian. 1902.
3981	(447) " "	. " " "
3982	(446) " "	. " " "
3983	(455) Gristhorpe Bay .	. Oolite Plant Beds. 1902.
3984	(450) " " .	. False-bedded Oolite Sandstones. 1902.
3985	(453) " " .	. Oolite Plant Beds. 1902.
3986	(457) " " .	. Boulder of Shap Granite. 1902.
3987	(448) Gristhorpe Bay, N. end .	"
3988	(456) Gristhorpe Bay .	. Oolites. 1902.
3989	(357) Cayton Bay, Scarborough	" "
3990	(356) " " .	Purple Boulder Clay. 1902.
3991	(358) " " .	Breaking waves. "
3992	(362) Between Cayton and Carnelian Bays, Scarborough.	Oolite Sandstones. "
3993	(360) Between Cayton and Carnelian Bays, Scarborough.	" " "
3994	(361) Between Cayton and Carnelian Bays, Scarborough.	Jointing in Oolite Sandstones. 1902.
3995	(363) Carnelian Bay .	. Purple Boulder Clay with Striated Limestone boulder *in situ*. 1902.
3996	(364) " " .	. Boulder Clay and Oolite Sandstone. 1902.
3997	(323) Scarborough Bay .	. Lenticular Bedding in massive Sandstones. 1902.
3998	(322) " " .	. Jointing in Oolite Sandstones. 1902.
3999	(319) " " .	. Oolites. 1902.
4000	(318) White Nab, S. of Scarborough.	" "
4001	(265) White Nab, S. of Scarborough.	Jointing in Oolite Sandstones. 1902.
4002	(266) White Nab, S. of Scarborough.	Oolite Sandstones. 1902.
4003	(267) S.E. corner of White Nab.	Denudation of Oolite Sandstones. 1902.
4004	(320) South of Nab, Scarborough.	False-bedded Oolite Sandstone. 1902.
4005	(848) Scarborough, Castle Hill	Kellaways Rock, Oxford Clay, and Corallian Beds. 1897.
4006	(350) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4007	(330) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4008	(328) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4009	(300) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4010	(302) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4011	(305) Scarborough, Castle Hill from East Pier.	Kellaways Rock, Oxford Clay, and Corallian Beds. 1902.
4012	(304) Scarborough, Castle Hill .	Kellaways Rock and Oxford Clay. 1902.
4013	(303) " "	Oxfordian and Corallian Rocks. "
4014	(301) Scarborough, Castle Hill, N.E. face.	Corallian Rocks. "
4015	(244) Scarborough, Castle Hill, N. side.	Oxfordian and Corallian Rocks. "
4016	(251) Scarborough, Castle Hill, N. side.	Oxford Clay faulted against Corallian Rocks. 1902.
4017	(249) Scarborough, Castle Hill, N. side.	Oxford Clay faulted against Corallian Rocks. 1902.
4018	(243) Scarborough, Castle Hill, N. side.	Corallian Rocks. 1902.

Regd. No.			
4019	(351) Scarborough, Castle Hill, West angle.	Corallian Rocks.	1902.
4020	(250) Scarborough, Castle Hill, N. side.	„	„
4021	(354) Scarborough, Castle Hill. .	„	„
4022	(325) Scarborough, Castle Hill, N.W. side.	„	„
4023	(289) Scarborough, Castle Hill.	„	„
4024	(353) „ „	Nodule Bed in Lower Calcareous Grit.	1902.
4025	(355) „ „	Nodule Bed in Lower Calcareous Grit.	1902.
4026	(247) Scarborough, North Cliff.	Oolites.	1902.
4027	(252) Cliffs at Peasholme, N.W. of Scarborough.	Oolites and Drift.	1902.
4028	(335) Scalby Beck . . .	V-shaped ravine cut through Oolites and Boulder Clay.	1902.
4029	(255) „	Cliffs of Boulder Clay.	1902.
4030	(332) „	Peak of Boulder Clay on Oolites.	1902.
4031	(336) Mouth of Scalby Beck .	„ „ „	„
4032	(253) Scalby, near Scarborough.	Boulder Clay on Oolites.	„
4033	(256) Scalby Beck . . .	Pinnacle of Boulder Clay on Oolites.	„
4034	(296) Mouth of Scalby Beck .	Stony Boulder Clay.	„
4035	(254) Scalby	Ripple-marks in Oolite Sandstone.	„
4036	(294) Scalby Beck . . .	Anticline in Oolites.	„
4037	(273) „	Oolites.	„
4038	(274) Coast N. of Scalby Beck .	„	„
4039	(276) „ „	„	„
4040	(275) „ „	„	„
4041	(272) „ „	Oolites under Boulder Clay.	„
4042	(284) Cromer Point, N. of Scarborough.	False-bedded Oolites.	„
4043	(287) Near Cromer Point . .	Oolites.	„
4044	(286) North of Cromer Point .	Lenticular Sandstones in Oolites.	„
4045	(268) Seamer Junction, near Scarborough.	Boulder of Shap Granite.	„
4046	(269) Crossgates Quarry, Seamer.	Corallian Rocks.	„
4047	(270) Crossgates Quarry, Seamer.	„	„
4048	(283) Coast S. of Cloughton Wyke.	Oolites.	„
4049	(280) Coast S. of Cloughton Wyke.	Plain of Marine Erosion.	„
4050	(281) Coast S. of Cloughton Wyke.	„ „	„
4051	(285) Coast S. of Cloughton Wyke.	„ „	„
4052	(282) Coast S. of Cloughton Wyke.	Oolite cliffs.	„
4053	(310) Hayburn Wyke, Undercliff, South of.	Landslips in Oolites.	„
4054	(311) Quarry S. of Hayburn Wyke.	Oolites.	„
4055	(316) Hayburn Wyke . .	Stream-course.	„
4056	(313) „	Double-waterfall.	„
4057	(307) „	Oolites.	„
4058	(309) „	„	„
4059	(315) „	Waterfall on shore.	„
4060	(308) „	Oolites.	„
4061	(312) „	„	„
4062	(306) „	Stream-course in Oolites.	„

Regd. No.			
4063	(314) Hayburn Wyke . .	Oolites.	1902.
4064	(222) Pickering. . . .	Corallian Rocks.	,,
4065	(215) Old Quarry near Castle, Pickering.	,,	,,
4066	(219) Old Quarry, W. side of Valley, Pickering.	,,	,,
4067	(216) Quarry S. of Newbridge, Pickering.	,,	,,
4068	(217) Quarry S. of Newbridge, Pickering.	,,	,,
4069	(220) Quarry S. of Newbridge, Pickering.	,,	,,
4070	(223) Quarry S. of Newbridge, Pickering.	,,	,,
4071	(837) Thomason Force, Goathland.	,,	1897.
4072	(838) Thomason Force, Goathland.	,,	,,
4073	(832) Robin Hood's Bay . .	Basalt boulders on bridge.	,,
4074	(1948 F) Cliffs near Saltwick .		,,
4075	(1947 F) ,, ,,		,,
4076	(1604 F) Cliffs E. of Whitby .		1895.
4077	(808) ,, ,, .	Oolite above Lias.	1897.
4078	(562) Cliffs ½ mile E. of Whitby.	Lias and Oolites.	,,
4079	(463) East Cliff, Whitby . .	,, ,,	1895.
4080	(563) Cliffs E. of Whitby . .	Sea-caves in Lias.	1897.
4081	(566) East Cliff, Whitby . .	,, ,,	,,
4082	(812) ,, ,, . .	Oolites on Upper Lias.	1897.
4083	(809) ,, ,, . .	,, ,,	,,
4084	(810) ,, ,, . .	,, ,,	,,
4085	(811) Whitby Old Town . .	Landslip Line.	,,
4086	(805) Whitby Harbour . .		,,
4087	(1932 F) Whitby Scaur . .	Lias and Oolites.	,,
4088	(1931 F) ,, . .	,,	,,
4089	(1929 F) ,, . .	,,	,,
4090	(567) ,, . .	,,	,,
4091	(641) ,, . .	,,	,,
4092	(564) ,, . .	,,	,,
4093	(464) ,, . .	,,	,,
4094	(636) ,, . .	Upper Lias.	,,
4095	(568) ,, . .	Lias at base of cliff.	,,
4096	(1930 F) ,, . .	Lias and Oolites.	,,
4097	(565) ,, . .	,,	,,
4098	(827) Cliffs W. of Whitby . .	False-bedded Oolites.	,,
4099	(829) ,, ,, . .	Drift upon Oolites.	,,
4100	(484) Cliffs at Upgang, W. of Whitby.	Drift, 80 to 100 feet.	1895.
4101	(1578 F) Cliffs at Upgang, W. of Whitby.	Boulder Clay and Sands.	1895.
4102	(488) Sandsend, N.W. of Whitby.	Lias.	1895.
4103	(828) Cliffs ¼ mile W. of Whitby.	Faulting.	1897.
4104	(594) Rigg Mill Beck, near Whitby		1895.
4105	(629) Cock Mill, S. of Whitby .	Waterfall.	,,
4106	(337) Runswick . . .	Middle Lias.	1897.
4107	(331) ,, . . .	Boulders on beach.	1897.
4108	(571) ,, . . .	Shap Boulder on beach.	1895.
4109	(573) Runswick Beach, N. end .	Boulders.	,,
4110	(332 F) Cliffs between Kettleness and Runswick.	Jet Mine in Lias.	1897.
4111	(1941 F) Staithes, Cliffs S. of .	Lias.	,,
4112	(1940 F) ,, East, Cliffs .	. .	,,

Regd. No.			
4113	(1939 F) Staithes, East Cliff .	Lias.	1897.
4114	(1942 F) Staithes	,,	,,
4115	(585) ,, ...	,,	1895.
4116	(1943 F) ,, ...	,,	1897.
4117	(842) Staithes, North Cliff .	Middle Lias.	,,
4118	(844) Staithes	Lias.	,,
4119	(843) Cliffs, Staithes . . .	Middle Lias.	,,

Photographed by H. W. MONCKTON, *F.G.S.*, 3 *Harcourt Buildings, Temple, E.C.* 1/4.

4120	(760) Osgodby Nab, N.W. End of Cayton Bay.	Estuarine Series, resting on Milleport Series. 1896.
4121	(1834) Osgodby Nab, N.W. End of Cayton Bay.	Estuarine Series, resting on Milleport Series. 1904.
4122	(1830) N.W. End of Cayton Bay.	Landslip of Boulder Clay. 1904.
4123	(1831) ,, ,,	,, ,, ,,
4124	(1832) ,, ,,	,, ,, ,,
4125	(1833) ,, ,,	,, ,, ,,
4126	(1554) Carnelian Bay, near Osgodby Nab.	Landslip of Boulder Clay. 1901.
4127	(1706) Carnelian Bay, near Osgodby Nab.	Site of Landslip of Boulder Clay, now washed away. 1902.
4128	(1702) Robin Hood's Bay . .	Boulder of Granite. 1902.

WALES.

ANGLESEY.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/4.

4129	(6236) South Stack Lighthouse, Holyhead.	Contortion. 1903.

CARNARVON.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/4.

4130	(6235) Diganwy, Llandudno .	Glaciated Boulder. 1903.
4131	(6239) Quarry, Great Orme's Head, Llandudno.	Carboniferous Limestone. 1903.
4132	(6240) Quarry near Summit, Great Orme's Head.	,, ,, ,,
4133	(6241) Quarry near Summit, Great Orme's Head.	,, ,, ,,
4134	(6242) Quarry near Summit, Great Orme's Head.	,, ,, ,,
4135	(6243) Quarry near Summit, Great Orme's Head.	,, ,, ,,
4136	(6245) Quarry near Summit, Great Orme's Head.	,, ,, ,,
4137	(6246) Quarry near Summit, Great Orme's Head.	Fossils in Carboniferous Limestone. 1903.
4138	(6247) Quarry near Summit, Great Orme's Head.	Carboniferous Limestone. ,,
4139	(6249) Quarry near Summit, Great Orme's Head.	,, ,, ,,

PEMBROKE.—*Photographed by* A. L. LEACH, 10 *Nithdale Road, Plumstead, S.E.* 1/2 and 1/4.

Regd. No.		
4140	(1) Tenby Quarry, S.W. of town	Carboniferous Limestone, with *Productus*. 1903.
4141	(2) ,, ,,	Carboniferous Limestone, with *Productus*. 1903.

Photographed by W. JEROME HARRISON, *F.G.S.*, 52 *Claremont Road, Handsworth, Birmingham.* 1/1.

4142	(749) Gasworks Section, Haverfordwest.	Llandovery	Rocks.	1897.	
4143	(300 F) Caerbwdy Valley, St. Davids.	Lower Cambrian Rocks.		,,	
4144	(302 F) Caerbwdy Valley, near Reservoir.	Glacial 'Tail.'		,,	
4145	(304 F) Caerbwdy Valley, St. Davids.	Lower Cambrian Rocks.		,,	
4146	(307 F) Caerbwdy Valley, St. Davids.	,,	,,	,,	
4147	(308 F) Caerbwdy Valley, St. Davids.	,,	,,	,,	
4148	(305 F) Caerfai Cliffs, St. Davids.	,,	,,	,,	
4149	(306 F) Caerfai Cliffs, St. Davids.	,,	,,	,,	
4150	(732) St. Non's Arch, St. Davids	,,	,,	,,	
4151	(732a) St. Non's Bay, St. Davids	,,	,,	,,	
4152	(733) ,, ,,	,,	,,	,,	
4153	(301 F) ,, ,,	,,	,,	,,	
4154	(311 F) ,, ,,	,,	,,	,,	
4155	(730) Cliffs S. of St. Davids .	,,	,,	,,	
4156	(734) ,, ,, .	,,	,,	,,	
4157	(735) ,, ,, .	,,	,,	,,	
4158	(731) Mouth of Porthclais, St. Davids.	,,	,,	,,	
4159	(747) Porthclais, St. Davids .	,,	,,	,,	
4160	(303 F) ,, ,, .	,,	,,	,,	
4161	(323 F) ,, ,, .	,,	,,	,,	
4162	(738) Ogof Golchfa, St. Davids.	,,	,,	,,	
4163	(743) ,, ,, .	Cambrian Conglomerate.		,,	
4164	(316 F) Porth-lisky, St. Davids .	Lower Cambrian Rocks.		,,	
4165	(317 F) Cliffs S. of Porth-lisky .	Marine denudation along joints.			1897.
4166	(318 F) ,, ,, .				,,
4167	(739) Porth'stinian, St. Davids .				,,
4168	(740) Porth Trevethan (?)				,,
4169	(746) Whitesand Bay, St. Davids.	Lingula Flags and Gabbro.			,,

THE ISLE OF MAN.

Photographed by C. A. MATLEY, *D.Sc., F.G.S.*, 90 *St. Lawrence Road, Clontarf, Dublin.* 1/4.

4170	(9) Langness, near Castleton .	Unconformity, Carboniferous on Manx Slates. 1901.

SCOTLAND.

EDINBURGH.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

Regd. No.			
4171	(A 17)	Salisbury Crags . .	Scarp of Dolerite Sill. 1902.
4172	(A 18)	" " . . .	Dolerite Sill in Carboniferous Rocks. 1902.
4173	(A 19)	" " . . .	" " " "
4174	(A 20)	" " . . .	Carboniferous Rocks overlying Dolerite. 1902.
4175	(A 21)	" " . . .	Spheroidal Dolerite. 1902.
4176	(A 22)	" " . . .	Columnar jointing in Dolerite. 1902.
4177	(A 23)	Arthur's Seat . . .	Coarse Tuff below Lion's Haunch. 1902.

FIFESHIRE.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

4178	(A 24)	By railway ½ mile W. of Burntisland Station.	Brecciated Carboniferous Strata. 1902.
4179	(A 25)	Dodhead Quarry, Burntisland.	Sill of 'White Trap.' 1902
4180	(A 26)	Dodhead Quarry, Burntisland.	Finger of Dolerite ('White Trap') in Carboniferous strata. 1902.
4181	(A 27)	Dodhead Quarry, Burntisland.	'White Trap' invading Carboniferous Rocks. 1902.
4182	(A 28)	W. of Kirkcaldy . .	Overthrust faults in Carboniferous Limestone. 1902.
4183	(A 29)	Shore, W. of Kirkcaldy .	Overthrust faults in Carboniferous Limestone. 1902.
4184	(A 30)	Shore, St. Monans . .	Dyke in Agglomerate of 'Neck.' 1902.
4185	(A 31)	Shore, Ardross . .	Undercut Cliff of Sandstone and Shale with thin Coals. 1902.
4186	(A 32)	S.E. of Newark Castle, Elie.	Small Volcanic 'Neck.' 1902.
4187	(A 33)	S.E. of Newark Castle, Elie.	" " "
4188	(A 34)	Shore, S.W. of St. Monans	Contorted Shale near Agglomerate of 'Neck.' 1902.
4189	(A 35)	"	Contorted Shale near Agglomerate of 'Neck.' 1902.
4190	(A 36)	Shore, Pettycur, Kinghorn.	Columnar Basalt. 1902.
4191	(A 37)	Shore, W. of Ardross .	Dyke. 1902.
4192	(A 39)	Shore, ½ mile E. of Kinghorn.	Amygdaloidal Basalt over Shales and Limestones. 1902.
4193	(A 40)	Shore, ½ mile E. of Kinghorn.	Amygdaloidal Basalt over Shales and Limestones. 1902.
4194	(A 41)	Elie	Agglomerate of 'Neck.' 1902.
4195	(A 42)	"	" " "
4196	(A 47)	"	Ripple-marked Sand on shore. 1902.

HADDINGTON.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

4197	(A 46)	Milsey Bay, North Berwick.	Agglomerate. 1902.

LINLITHGOW.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

Regd. No.		
4198	(A 43) Hound Point . .	Junction of Dolerite and underlying Sandstone. 1902.
4199	(A 44) " . .	Deposit of Cockles on Shore. 1902.
4200	(A 45) "	" " " "

RENFREWSHIRE.—*Photographed by* Professor S. H. REYNOLDS, *M.A., F.G.S., University College, Bristol.* 1/4.

4201	(A 48) Shore, Gourock . .	Contorted Gneiss, in boulder. 1902.
4202	(A 49) Shore, W. of Gourock .	Basalt dyke. 1902.
4203	(A 50) " " . .	" "
4204	(A 56) " " . .	Marine pot-holes. 1902.

STIRLINGSHIRE.—*Photographed by* H. W. MONCKTON, *F.G.S.*, 3 *Harcourt Buildings, Temple, E.C.* 1/4.

4205	(471) Sauchie Craig, 3 miles S.W. of Stirling.	Intrusive Dolerite on Carboniferous Limestone Series. 1895.
4206	(1825) Sauchie Craig, 3 miles S.W. of Stirling.	Intrusive Dolerite on Carboniferous Limestone Series. 1903.
4207	(1826) Sauchie Craig, 3 miles S.W. of Stirling.	Intrusive Dolerite on Carboniferous Limestone Series. 1903.

IRELAND.

ANTRIM.—*Photographed by* C. A. MATLEY, *D.Sc., F.G.S.*, 90 *St. Lawrence Road, Clontarf, Dublin.* 1/4.

4208	(1) Giant's Causeway . .	Straight and curved columns. 1903.
4209	(2) The Gobbins, Island Magee	Basalt Lavas. 1903.
4210	(3) " "	Chalk and Basalt. 1903.

**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4211	(5205) Colin Glen, Belfast . .	Yellow Sandstone, faulted against Glauconitic Sand and Red Marl. 1903.
4212	(5234) Hill's Port undercliff, Island Magee.	Old drainage channel outlets in Chalk cliff. 1902.

CORK.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4213	(5251) East Passage, Cork Harbour.	Longitudinal and transverse valleys. 1904.
4214	(5252) Weavers Point, Crosshaven.	Anticline in Old Red Sandstone. 1904.
4215	(5253) Weavers Point, Crosshaven.	Cleavage in contorted Old Red Sandstone. 1904.
4216	(5254) Near Weavers Point, Crosshaven.	Raised beach platform (preglacial) covered with beach and 'head.' 1904.
4217	(5255) Ringaskiddy Cliffs, Cork Harbour.	Cliff of Boulder Clay. 1904.
4218	(5256) Ballintemple Quarry, Cork.	Massive Carboniferous Limestone with tesselated joints. 1904.

Regd. No.		
4219	(5257) Ballintemple Quarry, Cork.	Chert Beds in Carboniferous Limestone. 1904.
4220	(5258) Carrigrohane Cliffs .	Massive Carboniferous Limestone. 1904.
4221	(5258*) „ „ . .	Rift in Carboniferous Limestone, filled with Gravelly Drift. 1904.

Photographed by W. B. Wright, *B.A., and* H. B. Muff, *B.A., F.G.S., 14 Hume Street, Dublin.* 1/2.

4222	(23 RDS) 350 yards E. of Howe Strand Coastguard Station, Courtmacsherry Bay.	Pre-glacial raised beach platform, raised beach, and overlying deposit. 1903.
4223	(24 RDS) Courtmacsherry Bay .	Raised beach gravel and sand, overlain by Boulder-clay. 1903.
4224	(24a) Courtmacsherry Bay .	Raised beach gravel and sand, overlain by Boulder-clay. 1903.
4225	(25 RDS) Ringabella Bay, N. side	Striated raised beach platform, overlain by Boulder-clay. 1903.
4226	(26 RDS) Nearly 500 yards E. of Howe Strand Coastguard Station, Courtmacsherry Bay.	Raised beach platform, Beach Sand, Lower 'Head,' Boulder-clay, and Upper 'Head.' 1903.
4227	(27 RDS) 80 yards S. of Myrtleville Cottage, entrance to Cork Harbour.	Raised beach deposits resting on rock platform and overlain by Lower 'Head.' 1903.
4228	(28 RDS) South side of Myrtleville Bay.	Blown-sand beneath Lower 'Head.' 1903.
4229	(29 RDS) Clonakilty Bay, S.E. of Ballinglanna Cove.	Boulder-clay over beach gravel on rock platform; also modern rock platform. 1903.
4230	(30 RDS) 400 yards E. of Simon's Cove, Clonakilty Bay.	Cemented gravel on raised beach platform. 1903.
4231	(31) Clonakilty Bay . . .	Beach gravel on rock platform, overlain by 'Head.' 1903.

Down.—**Photographed by* R. Welch, *Lonsdale Street, Belfast.* 1/1.

4232	(5236) Annadale Terra-cotta Works, Belfast.	Thin-bedded Sands and Laminated Clays. 1903.
4233	(5237) Annadale Brickworks, Belfast.	Glacial Sands, Laminated Clay, and Boulder-clay. 1903.
4234	(5238) South Quarry, Scrabo Hill.	Trias, veined and capped by sills of Dolerite and pierced by Dyke. 1903.
4235	(5239) South Quarry, Scrabo Hill.	Trias, veined and capped by sills of Dolerite and pierced by Dyke. 1903.
4236	(5241) Golf Links, Carnalea .	Ordovician Greywacke and crushed Graptolitic Shales; raised beach. 1903.
4237	(5242) Near Carnalea Golf Links	Ordovician Greywacke and crushed Graptolitic Shales; raised beach. 1903.

Photographed by C. A. Matley, *D.Sc., F.G.S.,* 90 *St. Lawrence Road, Clontarf, Dublin.* 1/4.

4238	(5) Near Rostrevor . . .	Cloughmore Boulder. 1902.

Dublin.—**Photographed by* R. Welch, *Lonsdale Street, Belfast.* 1/1.

4239	(5225) Esker, Greenhills . .	Irregular bedding of Gravels. 1902.

Photographed by C. A. MATLEY, *D.Sc., F.G.S.*, 90 *St. Lawrence Road, Clontarf, Dublin.* 1/4.

Regd. No.		
4240	(8) Needle Rock, Howth . .	Quartzite stack. 1902.
4241	(1) Killiney Bay . . .	Granite, Cambrian Rocks, and Drift. 1902.

KILDARE.—*Photographed by* C. A. MATLEY, *D.Sc., F.G.S.*, 90 *St. Lawrence Road, Clontarf, Dublin.* 1/4.

4242	(6) Poulaphouca Waterfall .	Ordovician Slates. 1902.
4243	(7) „ „ .	„ „ „

LEITRIM.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4244	(5249) 'Swiss Valley,' Glencar .	Landslip Valley. 1904.
4245	(2061) „ „	„ „ „

LONDONDERRY.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4246	(5240) Downhill . . .	North-west edge of Basalt plateau 1903.
4247	(5229) Portstewart Dunes .	Kitchen-midden Zones in Sand „
4248	(5229x) „ „	„ „ „

SLIGO.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4249	(5248) The Glen, Knocknarea .	Narrow Glen determined by Landslide and Joint-planes. 1904.
4250	(67p) „ „ .	Mosses forming a Calcareous Tufa on Limestone Cliff. 1904.
4251	(5245) Keshcorran Caves, Ballymote.	Series of Bone-caves along lower edge of Upper Carboniferous Limestone. 1903.
4252	(5245x) Keshcorran Caves, Ballymote.	Series of Bone-caves along lower edge of Upper Carboniferous Limestone. 1903.
4253	(5246) Keshcorran Caves, Ballymote.	Cave in well-jointed Carboniferous Limestone. 1903.
4254	(61p) Coffey Cave, Keshcorran .	Cave in well-jointed Carboniferous Limestone. 1903.
4263	(5247) Main Cave, Keshcorran .	Great pillar separating two mouths ; from interior. 1903.

WICKLOW.—**Photographed by* R. WELCH, *Lonsdale Street, Belfast.* 1/1.

4255	(5228) Summit, S. of Glenasmole	Gully cut into disintegrated Granite under Peat. 1904.

Well-sections in Cambridgeshire. By W. WHITAKER, *B.A., F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

THE well-sections of Cambridgeshire have been duly noted in seven of the nine Geological Survey Memoirs that deal with the county, as follows :—

1878. 'The Geology of the N.W. Part of Essex . . . with Parts of Cambridgeshire . . .' (Sheet 47 of the map.) Five wells.

1881. 'The Geology of the Neighbourhood of Cambridge.' (Sheet 51 S.W. of the map, with part of 51 N.W.) Ninety-one wells.

1886. 'The Geology of the country between and south of Bury St. Edmunds and Newmarket.' (Sheet 51 S.E. of the map.) Eleven wells.

1891. 'The Geology of Parts of Cambridgeshire and of Suffolk.' (Sheet 51 N.E. of the map, with part of 51 N.W.) Nineteen wells.

1893. 'The Geology of South-western Norfolk and of Northern Cambridgeshire.' (Sheet 65 of the map.) Eleven wells.

1900, 1904. 'The Cretaceous Rocks of Britain,' vol. i. and vol. iii. Two wells.

The earlier Memoir, the 'Geology of the Fenland' (1877), does not refer to Cambridgeshire wells.

I do not know of any further accounts of wells in the county having appeared; but (chiefly through the kindness of the late Mr. Ingold, well-sinker, of Bishops Stortford) descriptions of twenty-one wells have come to hand, and the meeting of the British Association at Cambridge seems to be a favourable time for making them public.

With the 139 already published, they bring the total to 160. No one of them is of any great depth or of special interest, but taken all together they form a useful addition to our knowledge of the county.

The figures for thickness and depth are for feet.
[Words in these brackets have been added by the writer.]

Balsham. Public Well near the Schools. 1896.

Shaft, bricked for 50 *feet. Made and communicated by* Mr. G. Ingold.

Water at 153½ feet.

		Thickness	Depth
Made ground		2	2
[Boulder Clay]	Grey clay	3	5
	Brown clay	5	10
	Blue clay	30	40
	Brown clay	5	45
[Upper Chalk]	Chalk	25	70
	Hard clunch	2	72
	Chalk	29	101
[? Chalk Rock]	Very hard clunch	4	105
[Middle Chalk]	Hard chalk	50	155
	Hard clunch	1	156
	Chalk	3½	159½

Mr. Jukes-Browne notes the very hard bed as Chalk Rock with doubt.

Bottisham. Police Station.

Communicated by Mr. W. M. Fawcett, *County Surveyor, from information from the Contractor,* Mr. Lack *of Cottenham.*

		Thickness	Depth
Made earth		2	2
[Lower Chalk]	Chalk marl	24	26
	Clunch	59	85
Gault (blue clay)		112	197
[Lower] Greensand		27	224

Bourn. East Hunts Waterworks, close to Old North Road Railway Station. 1888 ?

Communicated by Mr. M. Ffolkes.

Shaft and cylinders $169\frac{3}{4}$ feet, the rest bored.

Water-level, 100 feet down; lowered 45 feet, by pumping at the rate of about 60 to 70 gallons a minute, in 1888. In 1896 only 28 gallons a minute pumped.

	Thickness	Depth
Boulder clay [probably includes gault] .	164	164
[Lower Greensand] Sand	$8\frac{1}{4}$	$172\frac{1}{4}$
[? what] Soft blue clay	$20\frac{3}{4}$	193

If the clay be Kimeridge or Oxford Clay, the Gault must here cut down deeply into the Lower Greensand, or there must be a deep hollow of Boulder Clay.

Cambridge. In the Yard of Messrs. Foster & Co., Corn Merchants, at the Railway Station.

Communicated by Mr. W. M. Fawcett, *County Surveyor, from information from the Contractor,* Mr. Lack *of Cottenham.*

		Thickness	Depth
Made earth (soil and gravel)		13	13
[Chalk Marl]	Chalk Marl (blue and grey) .	4	17
	Clunch	$32\frac{2}{3}$	$49\frac{2}{3}$
Gault (Blue clay)		$130\frac{1}{3}$	180
[Lower] Greensand		28	208

Cambridge. Mr. Edwards' Brewery.

Made and communicated by Messrs. Isler & Co.

Water-level, $18\frac{1}{2}$ feet below the surface in the bore-tube.

Supply, 500 gallons a minute, with hand-pump.

		Thickness	Depth
Well, the rest bored		—	5
Gravel		6	11
[Gault] . . .	Gault [clay] .	123	134
	Rock . . .	1	135
[Lower Greensand]	Dead green sand .	4	139
	Rock and sand .	2	141
	Rock . . .	6	147
	Sand . . .	13	160

Castle Camps. Public Well. 1896.

Shaft. Made and communicated by Mr. G. Ingold.

Water at 115 feet.

		Thickness	Depth
Made ground		3	3
[Boulder Clay]	Blue clay	3	6
	Yellow clay	4	10
	Brown clay	7	17
	Chalky rubble	6	23
	Blue clay	62	85
	Light-grey clay	5	90
	Hurrock (chalky rubble) . . .	2	92
	Blue and light-grey clay . . .	26	118
	Hurrock (chalky rubble) with water	2	120

Castle Camps. BORING BY ROADSIDE, NEAR MALTING. 1884.

Made and communicated by Mr. G. INGOLD.

		Thickness	Depth
[Boulder Clay]	Yellow clay	4	4
	Blue clay	7	11
	Blue sandy loam	7	18
	Blue clay; hard layer of flints at 27 feet	22	40

Cherry Hinton. NETHER HALL ($1\frac{5}{8}$ MILE S.W. OF THE CHURCH).

Made and communicated by Mr. G. INGOLD.

1. Shaft 32 feet, the rest bored. 1893–94.

Water rose to within 40 feet of the surface. Plentiful supply.

		Thickness	Depth
Soil		4	4
[Lower Chalk]	Hard, loose clunch	41	45
	Chalk marl	$44\frac{1}{2}$	$89\frac{1}{2}$
	Coprolite-bed	$1\frac{1}{4}$	$90\frac{3}{4}$
[Gault, $142\frac{1}{2}$ feet]	Gault	$136\frac{1}{4}$	227
	Hard, green, sandy clay	2	229
	Black, sandy clay	$4\frac{1}{4}$	$233\frac{1}{4}$
[Lower Greensand, $50\frac{3}{4}$ feet]	Hard, rocky greensand	7	$240\frac{1}{2}$
	Rock, very hard	$1\frac{3}{4}$	242
	Sand	2	244
	Rock, very hard	$1\frac{1}{4}$	$245\frac{1}{4}$
	Hard sand	$2\frac{3}{4}$	248
	Sand, changing from light to dark green	36	284

2. Seventy yards N.E. of 1. Shaft 20 feet, the rest bored. 1893.

[Lower Chalk]	Clunch, Chalk marl	82 feet	92 feet.
	Coprolite-bed	10 inches	
Gault		9 feet 2 inches	

Mr. JUKES-BROWNE remarks that both sites are above the outcrop of the Totternhoe Stone, as drawn on the published 1-inch map (51 S.W.).

Cheveley. STUD FARM, MR. COOPER'S.

Made and communicated by Messrs. ISLER & Co.

Lined with 85 feet of tubes of 6 inches diameter, 12 feet down. Water-level 162 feet down. Supply about 1,200 gallons an hour.

		Thickness	Depth
Well (the rest bored)		—	20
[Boulder Clay]	Blue clay and chalk	22	42
	Blue clay and flints	5	47
	Blue clay and chalk	7	54
	Blue clay and flints	3	57
	Red rock [? boulder]	$\frac{1}{3}$	$57\frac{1}{3}$
	Blue clay, chalk, and flints	$10\frac{2}{3}$	68
	Blue clay and flints	3	71
	Red clay and flints	4	75
[Upper Chalk]	Hard chalk and flints	20	95
	Soft dry chalk	10	105
	Soft dry chalk and flints	57	162
	Soft dry chalk	37	199
	Hard chalk and flints	51	250
	Very hard chalk and flints	6	256
	Hard chalk and flints	56	312

Cottenham. PUBLIC SUPPLY, S.W. OF THE VILLAGE. 1898.

Communicated by Mr. W. B. FFOLKES.

About 17 feet above Ordnance Datum. Shaft of 8 feet diameter. Water-level $2\frac{1}{2}$ feet down.

[Gault ?]	Loose clay	20	25 feet.
	Rock	3	
[Lower] Greensand		2 ?	

Dullingham. MALTING, NEAR RAILWAY STATION. 1876.

Made and communicated by Mr. G. INGOLD.

Water at 146 feet.

Soil		3	160 feet.
Chalk	Soft chalk, no flints	50	
	Hard chalk, no flints	107	

Linton. 1. POLICE STATION. 1894. 2. VICARAGE. 1896.

Made and communicated by Mr. G. INGOLD.

1. Old well 12 feet, the rest bored. Water-level, 8 feet down.
2. Boring. Water 15 feet down, good supply.

	1.		2.
Gravel	12	120 feet	9
Chalk	108		111

Melbourn. POLICE STATION IN THE MIDDLE OF THE VILLAGE, JUST BEHIND INN. 1894.

Made and communicated by Mr. G. INGOLD.

A boring, tubed for 41 feet.
Water-level, $14\frac{1}{2}$ feet down. Yield, 5 gallons a minute.

		Thickness	Depth
Soil		2	2
[Lower Chalk]	Brown, sandy chalk, with thin layers of clunch	12	14
	Hard grey chalk [? Totternhoe Stone]	15	29
	Hard clunch	1	30
	Light-brown chalk, with layers of clunch, changing gradually to the next below	15	45
	Slate-coloured chalk marl	38	83

Pampisford. THE VICARAGE.

Made and communicated by Mr. G. INGOLD.

		Thickness	Depth
Made ground		2	2
[Middle and Lower Chalk]	Hard white chalk	43	45
	Light-brown clunch	15	60
	Softer brown chalk	107	167
	Hard clunch	3	170
	Light-brown chalk	6	176
	Blue marly chalk	4	180
	Brown chalk	10	190

Sawston. MR. EVANS' COTTAGES. 1885.

Bored and communicated by MR. G. INGOLD.

			Thickness	Depth
Mould			2	2
[Drift]	Gravel		5	7
	Sand		2	9
[? Middle and Lower Chalk]	Hard yellow chalk		11	20
	Softer white chalk		20	40
	Grey chalk		70	110

Shelford. A MILE E. OF STATION. DR. GASKELL'S. 1891.

Made and communicated by MR. G. INGOLD.

Water-level, 86½ feet down.

		Thickness	Depth
[Lower Chalk]	Loose chalk	75	75
	Solid clunch	6	81
	Soft chalk	7	88
	Hard chalk	30	118

West Wickham. ON THE GREEN, NEAR THE WHITE HART INN. 1884.

Made and communicated by MR. G. INGOLD.

Some water at 20 feet, more at 36 feet.

[Boulder Clay]	Blue clay	3	40 feet.
	Brown clay	2	
	Blue clay	35	

West Wratting. BY ROADSIDE, ON THE COMMON. 1885.

Bored and communicated by MR. G. INGOLD.

Boulder Clay, 51 feet. No water.

Whittlesford. PUBLIC WELL. 1886.

Bored and communicated by MR. G. INGOLD.

Water-level 11 feet down.

		Thickness	Depth
[Drift]	Gravel	14	14
	Brown marl	10	24
Chalk	White chalk, brown in places	31	55
	Loose chalk	2	57
	White chalk	28	85

The following is an addition to a description in the Memoir on 'The Geology of Parts of Cambridgeshire and of Suffolk' (1891).

Newmarket. WATERWORKS.

Made and communicated by MESSRS. ISLER & CO.

Made ground		3	90 feet.
[Chalk]	Dry chalk	20	
	Chalk	45	
	Clunch	22	

Investigation of the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, and at various localities in the East Riding of Yorkshire.—Report of the Committee, consisting of Mr. G. W. LAMPLUGH (*Chairman*), Mr. J. W. STATHER (*Secretary*), Dr. TEMPEST ANDERSON, Professor J. W. CARR, Rev. W. L. CARTER, Mr. A. R. DWERRYHOUSE, Mr. F. W. HARMER, Mr. J. H. HOWARTH, Rev. W. JOHNSON, Professor P. F. KENDALL, Mr. E. T. NEWTON, Mr. H. M. PLATNAUER, Mr. CLEMENT REID, *and* Mr. THOMAS SHEPPARD.

OWING to circumstances it has only been found possible during the present year to complete the investigation of the deposits at Kirmington and Great Limber, but it is hoped in the future to extend operations to Bielbecks and several other sections that require further elucidation.

Kirmington Section.

The work on this important section, which was begun last year, has now been carried to a successful conclusion; and the results show that in some respects this section has no known parallel in English drift sections. It will be remembered that, as described in last year's report, a brickyard is worked at this place in a mass of warp or clay containing estuarine shells with a freshwater bed at its base, and that this deposit is overlain by a bed of coarse flinty shingle, above which in one part of the pit there is found a few feet of red stony clay believed to be a boulder clay. The boring last year proved the presence of a glacial clay at some depth beneath the warp. The chief object of our investigation has been to discover the relationship of the fossiliferous warp to the Glacial Series, and to carry the boring through the superficial deposits to the chalk, which was not reached last year.

During June of the present year a new boring was carried out under the personal supervision of the Chairman and Secretary, with the assistance of Mr. G. W. B. Macturk. Mr. Villiers, well engineer, of Beverley, undertook to put down the boring, and the Committee desire to express their indebtedness to him for the ready manner in which, at considerable personal inconvenience, he met their wishes as to the time and conditions of the work.

In order to secure a section in another part of the pit, the site of the new boring was fixed at a point 80 yards north-east of last year's boring. Although at the spot chosen the warp used for brickmaking had been excavated to a depth of 5 feet below the level of its base at the former site, this material was passed through in the new boring to a further depth of 3 feet, so that its base is here 8 feet below its position in the former boring. The total depth attained by the new boring, combined with the height of the open section, was 96 feet, or 41 feet lower than was reached last year. The surface of the chalk lay much deeper than was anticipated, and the borings seem to prove that the surface features of the locality are not due to the presence of chalk, as hitherto supposed, but that the rising ground has been formed by the erosion of a thick and complex mass of drift.

The diameter of the second boring was at first 4 inches, narrowing

to 3 inches at a depth of 15 feet. It was found necessary to line the boring with tubes throughout.

The section seen in the brickyard and proved in the borehole was as follows :—

	Ft.	In.
Surface soil (at 95 feet above O.D.)	1	0
Clay with foreign stones (see NOTE A)	4	0
Well-worn shingle, principally of battered flints	8	0
Laminated warp with estuarine shells, and at its base a thin seam of peat associated with a sandy warp containing freshwater shells in one part of the pit (see NOTE B)	18	6
Clean yellow sand, with pebbles of chalk and flint	4	9
Red clay passing downwards into tough reddish-brown clay	7	6
Purple clay, streaked with silt and loam, passing downwards into tough purple clay with small stones including some erratics (see NOTE C)	10	6
Stoneless purple clay	5	0
Stoneless yellow clay	6	0
Flinty gravel	4	6
Yellow clay and loam with small drift pebbles	5	0
Yellow sand, full of well-rounded quartz grains and specks of chalk	8	0
Yellow sand and laminated clay	4	0
Tough compact lead-coloured clay, with a few small foreign pebbles (see NOTE D)	5	3
Tough yellow clay streaked with chalk	1	0
Solid chalk and flint	3	0
Total	96	0

NOTE A.—Among the erratic stones which this clay contains the following were identified: Basalt, porphyrites, rhomb-porphyry, grits, &c.

NOTE B.—Mr. Clement Reid records from this bed *Scrobicularia piperata*, *Rissoa ulvæ*, *Tellina balthica*, *Cardium edule*, *Mactra subtruncata*, *Mytilus edulis*, and abundant *foraminifera* (see 'Mem. Geol. Survey, Holderness,' p. 58).

Mr. Reid has examined the plant remains obtained by the Committee from the band at the base of the warp and reports as follows : 'The plant remains obtained by Mr. Stather from the peaty warp belong to the following species :—

Ranunculus sceleratus, Linn.	*Atriplex ?*
Eupatorium cannabinum, Linn.	*Zannichellia pedunculata*, Reichb.
Aster Tripolium, Linn.	*Scirpus setaceus*, Linn.
Lapsana communis, Linn.	,, *maritimus*, Linn.
Mentha aquatica, Linn.	,, sp.
Labiate (much crushed)	*Carex incurva*, Lightf.

'The list is a small one, but it indicates estuarine conditions, and suggests a sub-arctic climate. With one exception the plants are still to be found in the neighbourhood of the Humber ; but one of them, *Carex incurva*, is a sea-coast sedge not now ranging south of Holy Isle.

'A striking peculiarity of the deposit is the abundant remains of the estuarine sedge, *Scirpus maritimus*, a plant which, growing out of a few inches of water, tends to form a thick belt through which few drifted seeds would find their way. In view of the abundance of this sedge in the bed now examined and of the like-growing reed, *Phragmites communis*, in the deposit which I searched some years ago, the small number of other plants yet detected is not surprising. Land plants are only represented by two fruits of *Lapsana*, perhaps brought by birds. These fruits of *Lapsana*, as well as those of the sea-aster, are considerably smaller

than my recent specimens, but I have not yet had an opportunity of comparing them with fruits of the same species near their northern limit.'

From the fresh-water shell-bed associated with the peat Mr. E. T. Newton has determined *Planorbis spirorbis*, *Bithynia tentaculata*, with probably *Candona* (an Entom.).

NOTE C.—In general appearance this clay resembles the purple clay of Holderness. Among the pebbles washed out of 30 lb. of the clay brought up by the augur, chalk and flint greatly predominate, but the following rocks were also represented: Red Chalk, black flint, Spilsby sandstone, ferruginous pebbles, quartz, basalt, and porphyrites, besides many undeterminable small pebbles.

NOTE D.—This clay is hard and tough and very different from A and C both in texture and colour. It resembles in colour the basement clay of Holderness. The pebbles are smaller in size than in C, and there is a still higher proportion of chalk and flint. Among the erratic pebbles the following are recognisable:—Basalt, porphyrite, sandstone, black flint, grit, quartz, &c.

Great Limber Section.

A boring was also put down under the supervision of Mr. G. W. B. Macturk, who kindly undertook to aid the Committee in this manner, at the Great Limber brickyard, three miles south-east of Kirmington, where there is a further development of warp and sand, believed by Mr. C. Reid to be of the same age as the Kirmington deposit, though no fossils have been found in it. The section seen in the brickyard and proved in the boring was as follows:—

	Ft.	In.
Surface soil and clay with stones (at 110 feet above O.D.)	4	0
Loamy sand contorted and mixed with warp	4	0
Laminated blue warp with sandy streaks	10	0
Pan	1	3
Current bedded sand	4	9
Sharp sand	8	0
Flint, sand, and rounded chalk pebbles	5	0
Solid chalk with flints	1	0
Total	38	0

In comparing this section with the one at Kirmington it should be noted, (1) that no shells have been found in the laminated warp at Limber; (2) that the warp does not rest on glacial clays; and (3) that the base of the Limber warp is 92 feet above O.D., or 28 feet higher than that of Kirmington.

It would be premature to discuss the problems raised by these interesting sections until the work of the Committee has been carried further. For the present, therefore, we desire only to record the data thus far obtained.

The thanks of the Committee are due to Mr. W. H. Crofts and Mr. G. W. B. Macturk for practical help in many ways; also to the Earl of Yarborough (landlord), E. P. Hankey, Esq. (agent), and the occupiers of the brickyards—Mr. Hervey and Mr. Jno. Housan—for permission to put down the borings.

The Committee request to be reappointed, with power to use the unexpended balance of last year's grant.

Investigation of the Fauna and Flora of the Trias of the British Isles. —Second Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. J. LOMAS (*Secretary*), Professor W. W. WATTS, Professor P. F. KENDALL, *and* Messrs. H. C. BEASLEY, E. T. NEWTON, A. C. SEWARD, *and* W. A. E. USSHER. (*Drawn up by the Secretary.*)

(PLATES III.–VI.)

THE work of the Committee has been continued during the past year, and reports have been received from Mr. H. C. Beasley on 'Footprints from the Trias, Part II,' dealing with Rhynchosauroid and Chelonoid forms; from Mr. E. T. Newton, F.R.S., on 'The Triassic Fossils (excluding Rhætic) in the Museum of the Geological Survey at Jermyn Street, London;' and from Dr. A. Smith Woodward, F.R.S., on 'The British Triassic Fossils in the British Museum.'

Complete lists of the Triassic fossils in the two great London museums are included in the reports, together with notes on the more interesting forms, and valuable references are given to works and papers in which the specimens are described or noticed.

In the next report the Committee hopes to present similar lists and notes from museums in the provinces. Assistance in this direction has already been promised, and some progress has been made towards tracing types and interesting specimens stored in public and private collections.

It is essential that the fossils should be correctly named, and those who have the keeping of them are reminded that any specimens sent to the Secretary will be acknowledged and returned after they have been submitted to specialists for determination.

I. *Report on Footprints from the Trias, Part II.* *By* H. C. BEASLEY.

Rhynchosauroid Forms. D 1–5 and E.

In the first portion of this report footprints more or less resembling those originally attributed to the Cheirotherium were described. It is proposed to deal next with those bearing some resemblance to the footprints attributed to the Rhynchosaurus, and for which the term Rhynchosauroid has been suggested.

We are met with some little difficulty at the outset owing to the fact that no figures were given of the footprints described by Dr. O. D. Ward,[1] and which were referred to by Professor Owen,[2] in his paper on *Rhynchosaurus articeps*, neither has the writer been able to find in the Shrewsbury Museum or elsewhere, up to the present, the type specimens. It is not easy to find any example that will exactly tally with the description

[1] *British Association Report*, 1839, 'On Footprints and Ripplemarks of the New Red Sandstone of Grimshill, Shropshire,' by O. D. Ward, M.D.

[2] *Trans. Camb. Phil. Society*, vol. vii. p. 355, April 11, 1842. 'Description of an Extinct Lacertian Reptile, *Rhynchosaurus articeps* (Owen), of which the bones and footprints characterise the Upper New Red Sandstone of Grimshill, near Shrewsbury, by Richard Owen, F.G.S., Hunterian Professor at the Royal College of Surgeons.'

either at Grimshill or in other Lower Keuper exposures. Dr. Ward says 'the footmarks differ from those of Cheirotherium in having only three toes armed with long nails directed forwards and not spreading out, and one hind toe, pointing backwards, having a long claw. No impression of the ball of the foot in this example, but in another there are three toes and a depression for the ball not unlike that of a dog.' Owen in his paper compares them with the footprints from Shrewley, described by Murchison and Strickland, but says 'they differ from them' (the Shrewley prints) 'in giving more distinct terminations to the terminal claws and less distinct impressions of the connecting web. The innermost toe is more diminutive, and there is an impression, always at a definite distance from the fore toes, of a hind toe pointing backwards, and which seems to have only touched the ground with its point.' The Shrewley prints will be dealt with later, but it may be noted that in our Lower Keuper Sandstones in Cheshire and Shropshire no definite trace of webbing on this form has been observed (the Shrewley prints, it should be noted, are from the Upper Keuper Sandstones). It is also difficult to recognise in them the backward pointing digit. A three-toed print is in Mr. Beeby Thompson's collection with a mark in the rear, which it has been thought may represent the point of a backward-pointing toe. A somewhat smaller but similar print has been found at Runcorn with a mark in the same position in the rear, but several similar marks are scattered close to the print, and in no case have they quite the appearance of the print of a claw. Another print of the same form, but with a short toe projecting at right angles to the rest of the foot, comes from Storeton. These seem to be varieties of the print described as D 1.[1]

D 1. A four-toed print of which frequently the impression of only three toes is preserved; these three, presumably II–IV, gradually taper from the roots to the ungual termination, the breadth about the middle being 5 mm. when the length is 35 mm. They gradually decrease in size from IV–II. Where I is present it is much shorter than the others, but seems to vary in relative size, being in some prints more than one-half the length of II, at others not a quarter that size; all the digits are terminated by sharp claws; the three digits lie more frequently side by side, though sometimes they diverge, and I usually diverges most. The usual length of the print is 3 or 4 cm., but occasionally instances are met with showing much smaller impressions. The impression of V has been noticed occasionally. The proximal ends of the digits are often in actual contact, but they are also frequently found with a slight space intervening. There is no trace of the 'ball' mentioned by Dr. Ward, or any portion of the foot beyond the digits themselves. The width of the print at the base of the three digits is about equal to half the length of the middle or III digit (pl iii.).

D 1. $\frac{1}{1}$.

A very noticeable feature in these prints is a frequent lateral curvature with the concavity towards the inner side, and the claws are bent aside in this direction as if unable readily to penetrate the mud in which the impressions were made.

Where the digits lie close side by side the cast of the impressions is

[1] All the figures are natural size, except E, p. 279.

Slab of dark red sandstone from Runcorn, with natural casts of D1.
About one-fourth actual size.

From photograph by Mr. JAMES WAITE, of Liverpool.
Collection of Mr. H. C. BEASLEY.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

FIG. 1.—Natural casts of D2 from Daresbury.
About four-fifths natural size.

From photograph by Mr. RICHARD EDMONDS, of Liverpool.
Dr. RICKETT'S Collection, Museum of Liverpool University.

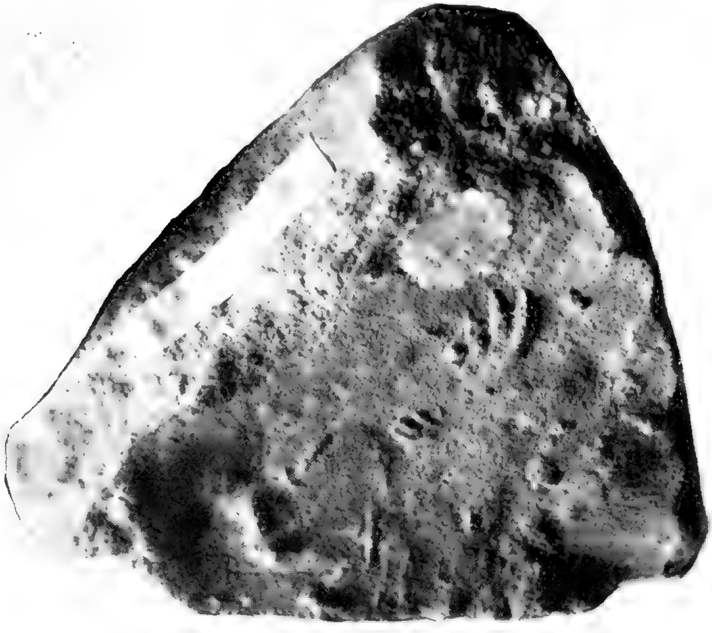


FIG. 2.—Natural casts of E from Storeton.
About two-thirds natural size.

From photograph by Mr. RICHARD EDMONDS, of Liverpool.
Collection of Mr. H. C. BEASLEY.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

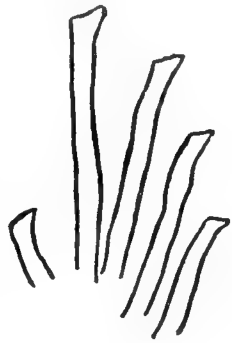
strongly convex, as if the middle of the digits sank more deeply into the mud than their roots or terminations, the digits themselves being bent backwards.

When the claws are bent sideways they frequently present a triangular impression, as if much compressed laterally ; there is, however, a possibility of this being the result of movement.

A much larger print with quite the same character is occasionally found with the IV digit measuring over 6 cm. in length. It also shows the same lateral bend of the digits and claws. It is, however, not advisable to separate it from the type just described, and it may be included under D 1. The frequent absence of any trace of the V digit may either be caused by its being too short to touch the ground, or it may have been turned backwards and only occasionally have left traces of its presence.

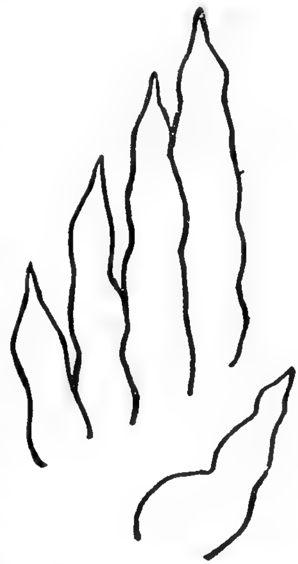
D 2. There is another form found frequently in the Runcorn district, and occasionally at Storeton and elsewhere, in which the digits are about the same length as in D 1, but are not half the thickness, and are more widely separated at the base. A small but typical example is in the Museum of the University of Liverpool, and was obtained by the late Dr. Ricketts from Daresbury. It shows the five toes, and a little in its rear there is the impression of the corresponding forefoot, or rather what we may suppose to be such, which agrees with it in form, but is somewhat less than one-half the size. In this example the digits are quite straight, but they are often found bent, and with a sharp flexing of the joints of the phalanges which contrasts strongly with the more regular curvature of D 1 (pl. iv., fig. 1).

D 2. $\frac{1}{1}$.



The digits often have blunt, slightly thickened terminations, and no trace of a claw. This feature seems to occur very frequently in footprints, and it is uncertain whether it implies a difference in structure or is merely the result of a movement of the extremity when the print was made.

D 3. $\frac{1}{1}$.—Left pes.



D 3. A third form, in some respects resembling these, has been found in South Staffordshire by Mr. Beeby Thompson in beds rather higher in the Lower Keuper than the footprint beds of Cheshire. It differs principally from D 1 in the form of the V digit. The first is also rather longer than in D 1 and 2.

The prints are described and figured by Dr. A. S. Woodward ('Geol. Mag.,' N.S., Decade IV., vol. ix., pp. 213–217, May 1902). He says : 'The total length of the fore-foot is 0·04 M., and the maximum breadth 0·025 M. As in the hind-foot, the terminal phalanges are very distinctly shown to have the form of sharp claws, and the V digit is slightly opposed to the remainder. The joints of digits I to III are well seen, and comprise respectively two, three, and four phalanges ; but digits I and V are unfortunately indistinct.

'The hind-foot is relatively more elongated than the fore-foot, and measures approximately 0·07 M. in length and 0·038 M. in maximum breadth. The first four toes successively increase in size outwards, but the fifth is very small—perhaps, indeed, the smallest. The number of phalanges is two, three, or four in digits I to III respectively, and specimen No. 2 (footprint) shows clearly there are five in digit IV. The palm of the foot, so to speak, is of considerable length, and in the hind-foot much narrowed posteriorly.' A small form about 25 mm. in length, very closely resembling this, has been noticed from Runcorn on slabs in University Museum, Liverpool, and a less perfect one in the Warrington Museum from the same place.

This form differs from D 1 in the greater length of the I digit, in the presence of the impression of the palm which is never seen in the impressions D 1 and 2, in the opposable V digit, and also in the well-marked joints of the phalanges. Digits II–IV would, however, certainly coincide with many of the imperfect D 1 prints. This print is fairly common in the Keuper in South Staffordshire, though seldom found nearly so perfect as those described above.

Dr. Woodward suggests that these prints may be referred to Rhynchosaurus. He also refers to the slab from the Upper Keuper of Shrewley, Warwickshire, described and figured by Murchison and Strickland,[1] and now in the Warwick Museum, as footprints of Rhynchosaurus. This slab, owing to its long exposure in the museum, has become deficient in the detail, but from a lithograph issued many years ago and from a sketch made in 1897 it is clear that it differs from D 3. There are nine distinct pairs of feet, and in every case the fore and hind feet are side by side, the latter, the larger print, being on the outside, whereas in the South Staffordshire example the manus is in a line with and considerably in advance of the pes. In the Shrewley slab the digits I–IV of the hind foot are distinctly webbed, and there is no trace on any of the impressions of a fifth digit.

D 4. In including these under the Rhynchosauroid prints they may be distinguished as D 4. Pes only four digits shown, decreasing in size from II to IV—all terminated by claws—distinct mark of webbing connecting the digits claws projecting beyond it; total length of print, 4 cm.; breadth, 25 mm.

D 4. $\frac{1}{1}$.—Left pes.

Manus, three stout toes only shown, with indistinct webbing; total length, 2 cm.

These prints are interesting, as, besides giving a complete series, there is a line between the rows of impressions the whole length of the slab, apparently caused by the dragging of a tail. In the forms D 1 and 3 the writer has failed to see any certain trace of webbing, though others have thought they have seen indications. It must be borne in mind that the example we have from Shrewley is from a bed of sandstone in the Upper Keuper, underneath which the Rev. P. B. Brodie has noticed the presence of shells of Lamellibranch Mollusca, and in the same bed of sandstone casts of *Estheria minuta* are frequent; so that the conditions

[1] *Trans. Geol. Society*, 2nd series, vol. v. p. 339, plate xxviii.

were different from those under which the Lower Keuper sandstones were formed.

This form might be compared with *Saurichnites rittlerianus* (Hochstetter), represented by a cast in the British Museum of Natural History (R 1474) from the Lower Permian of Semil, Bohemia. The quarry at Shrewley has yielded many other prints which still require working out.

D 5. A print of rather different proportions may conveniently be included in this group, as there is a possibility of its representing the corresponding manus to one of the foregoing forms. It has not yet been seen in such a position as altogether to warrant such an assumption, though it is generally associated with prints of D 1.

D 5. $\frac{1}{1}$.—Manus ?

In D 5: Only four digits are usually shown, No. IV, about 2 cm. in length, being the longest. No. I is the shortest, 1 cm. The breadth of IV in the widest part is 4 mm.

The digits are divergent, tapering, and somewhat laterally curved. They are in contact at the roots (the articulation with the metacarpals ?), which are marked by the presence of round pads. The width of the impression here is 15 mm.

This form will be seen to differ from D 1 not only in its smaller size but in its greater proportional breadth and the more rapid taper of the digits.

E. There is a small footprint described[1] as E=*Rhynchosaurus minimus* (Morton).

This was first described from fairly perfect examples of both pes and manus from Storeton, and afterwards a complete series of seven pairs of the same prints was found at Runcorn.

E. $\frac{3}{2}$.—Left pes.

Pes: The outer digit, probably IV, is the longest, 10 mm., on the inner side of II, and slightly in the rear is a very short hallux.

II–IV are divergent, curve inwards, and terminate in sharp claws. They frequently have very blunt ends; from the centre of each a fine sharp claw projects. There is no distinct mark of a claw on the hallux. The breadth of the footprint across the proximal ends of the digits is 1 cm. (pl. iv., fig. 2).

The manus, represented by four detached toes, is much smaller than the pes, being 5 mm. long by 7 mm. broad. The digits are less divergent than those of the pes; their diminutive size prevents the recognition of any details in a coarse material like sandstone.

In neither the pes nor manus is there any trace of webbing. On the Runcorn slab there are four pairs of impressions of right feet and three of left. The impressions of a fore and hind foot are in every case side by side, the hind foot being on the outside, with an interval of about a centimetre between it and the manus. The length from one of the feet to the next impression in front is 10 cm., and a line drawn outside the hind feet on one side would be 6 cm. distant from a corresponding line outside the left.

This is a very common form, and its size varies greatly, some prints of the pes reaching 2 cm. in length. The form of the print also varies very

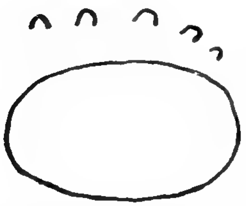
[1] *Proc. Liv. Geol. Society*, vol. vii. 1895, p. 402.

much, a variation probably due to mechanical causes and not to any difference in the form of the foot. A form rather longer than the type is seen on slabs from Coven, South Staffordshire, in the Victoria Institute, Worcester, and in the Liverpool Museum.

Chelonoid Forms. F 1–2.

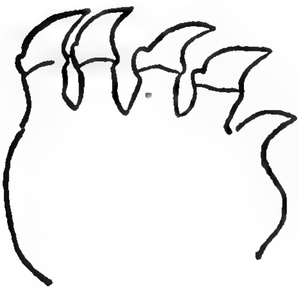
The distinguishing features of the prints included in this group are the presence of a distinct palmar surface covering a large portion of the area of the print and of short strongly clawed digits.

F 1. $\frac{1}{1}$.



F 1. The most common and also the simplest form that has been seen consists of an oval gently rounded surface measuring about one inch by three-quarters of an inch, with marks of four or five claws a little in front of the longer margin. This is fairly common both at Runcorn and Storeton; the best example is in a slab from Storeton, in the Bootle Museum, No. 9, which is nearly covered with them. The original label is still attached, 'Footmarks from Storeton of Lizards and Tortoises, Natural History Society.' It is identical with *Saurichnites perlatus* [1] (Fritsch), and Mr. Morton includes it in his *Chelone ? subrotundus.*

F 2. $\frac{1}{1}$.—Manus ?



F 2 This is a much less simple form, and presents some difficulties of interpretation. It consists of an irregular oblong about the same size as the oval of F 1, divided into regions by slight depressions: from the front of this project four short cylindrical parallel digits, and a fifth indistinctly marked is often present. Each digit is armed with a strong, sharp claw, having a slight protuberance at its base. The claws are almost sickle-shaped, and appear to have pointed obliquely upwards, but there is a difficulty in making out their normal position.

The best example seen is from Storeton (pl. v.). It measures 30 mm. wide by 33 mm. from the posterior margin of the print to the outer boundary of the claws. The length of the II digit to the root of the claws is 5 mm., and the claw itself about 7 mm. Although the slab of stone is of considerable size, it unfortunately contains but this one recognisable print of this form. From other specimens it would seem to make a track 8 inches wide with length of stride 9 inches, the right and left prints alternating. Further observations are required to confirm this. There is a large slab showing these prints in the Liverpool Museum. Some prints have recently been found at Runcorn of approximately the same size, but with the digits fully 1 cm. long, not including the claw, or twice the length of the type. The same elongation of the digit is also seen on a slab in Liverpool University Museum, whilst in another print close by, apparently made by the same individual, the digits are of the typical proportions.

The general appearance of the prints suggests a burrowing habit and a resemblance to the foot of the common mole. It was described and figured by the writer in 1897,[2] together with a note from Professor Seeley

[1] Letter to the writer.

[2] Observations regarding a Footprint from the Keuper Sandstone at Storeton,

Slab of grey sandstone from Storeton, with casts of F2, D1, &c., and tracks of Invertebrates. About one-third actual size.

From photograph by Mr. JAMES WAITE, of Liverpool.
Collection of Mr. H. C. BEASLEY.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

Skull of *Capitosaurus stantonensis*, from Stanton, North Staffordshire. About half natural size. Natural History Museum, South Kensington.

Illustrating the Report on the Investigation of the Fauna and Flora of the Trias of the British Isles.

on the apparent structure of the foot, pointing out its resemblance to that of an Anomodont reptile. Mr. Morton includes this form also in *Chelone subrotundus*. The print is, however, so different from F 1 that it is advisable to distinguish it as F 2.

Prints of this form are occasionally found with the posterior margins of two prints in contact and the digits pointing outwards. This is probably the origin of very peculiar print described and figured by Dr. Black from Weston.[1]

The Chelonoid forms will also include the footprints described and figured by Dr. Duncan,[2] from Dumfriesshire, and several of those in Sir William Jardine's work on the 'Ichnology of Allandale' as well as many of the Elgin footprints. The examination of the Scotch footprints is not concluded, and their description must be deferred.

Incertæ Sedis. I and M.

There are many forms which can hardly be included in any of the groups that have been dealt with, but which may be described here.

I. This form was described and figured in 1894 by Mr. O. W. Jeffs,[3] from a specimen now in Chester Museum (No. 129, from Storeton), and mentioned by Mr. Morton as *Rhynchosaurus tumidus* and also described and figured by the writer[4] in 1898 from the Chester and other examples.

I. $\frac{1}{1}$.

A small four-toed print about 25 mm. long by about half that width. Three stout fleshy digits lie close and parallel to each other, and a fourth much shorter digit on one side somewhat in the rear of the adjoining one. All the digits have blunt extremities beyond which project fine sharp claws. The divisions between the digits are usually very indistinct, but appear to be rather more than half the total length of the print. The posterior margin is not very well defined.

There are a number of very small footprints which are too imperfect generally to be described in detail; one, however, found at Hilton Beck, Westmoreland (St. Bees Sandstone), and at Runcorn, might be noticed here.

M. $\frac{1}{1}$.

M. A very small print of triangular outline, the apex being the heel, three stout toes, the middle one rather longer than the others, which diverge equally on either side; no traces of claws; length of middle digit more than half that of the whole print; length of print 5 mm. Spread of the toes at the distal extremities 4 mm.

There remain for further investigation many other prints from the Lower Keuper as well as those from the Upper Keuper and those from Scotland. The tracks of invertebrates are very numerous (pl. v.), and

with a Note on the probable Structure of the Foot by Professor H. G. Seeley, F.G.S., &c., by H. C. Beasley, *Trans. Liverpool Biol. Soc.*, vol. xi. p. 179, pl. vii. (1896–97).

[1] Observations on a Slab of New Red Sandstone from the Quarries of Weston, near Runcorn, Cheshire. Certain Impressions of Footprints in other Marking, by J. Black, M.D., *Q.J.G.S.*, November 1845, p. 479.

[2] An Account of the Tracks and Footmarks of Animals found impressed on Sandstone in the Quarry of Corncockle Muir in Dumfriesshire, by Rev. H. Duncan, D.D., Minister of Ruthwell, *Trans. Roy. Soc. Edin.*, vol. xi. 1828.

[3] *Journal Liverpool Geological Association*, vol. xiv.

[4] *Proc. Liverpool Geological Society*, vol. viii. p. 234.

though their origin is very uncertain it is advisable that they should be recorded.

NOTE.—Mr. Morton, in his appendix to the 'Geology of the Country around Liverpool,' p. 299, gives names to six forms which he thinks cover all the footprints found in the district. He left a collection made by him of photographs, prints, and drawings of footprints, to which he has attached the names given by him, so that there is no difficulty in correlating his species with those described in this report, viz.—

Cheirotherium	storetonense	=	A I, II & III.
,,	minus	=	B I & II.
Rhynchosaurus	articeps	=	D I & II.
,,	? minimus	=	E.
,,	? tumidus	=	I.
Chelone ?	subrotundus	=	F.

II. *Notes on the Triassic Fossils (excluding Rhætic) in the Museum of the Geological Survey at Jermyn Street, London. By* E. T. NEWTON, *F.R.S., F.G.S.*

The number of Triassic fossils (excluding those from the Rhætic deposits) preserved in this museum is not great, but some of them are of exceptional interest.

Among the imperfect plant remains *Voltzia* is the only genus that has been recognised, and the specimens are by no means satisfactory.

The little crustacean *Estheria minuta* is represented by examples from several localities.

Marine mollusca had not been recognised in the English Trias until about eleven years ago, when Mr. Percy Richards discovered specimens in a greenish gritty clay at Shrewley, near Warwick, which he presented to this museum. Other examples were obtained by the late Rev. P. B. Brodie, which are now in the British Museum at South Kensington. The two series formed the basis of Mr. R. B. Newton's paper in the 'Journal of Conchology,' vol. vii. 1894.

The remains of fishes are fairly abundant in the Trias, Elasmobranchs and Ganoids being represented in this collection, the former by spines and teeth and the latter by more or less perfect bodies. The unique *Dipteronotus cyphus* from the Keuper of Bromsgrove calls for special notice, as it is the type of the genus and species which was described by Egerton in 1854, and the form does not appear to have been again met with during the fifty years that have passed since that paper was published.

There is a portion of a lower jaw of a Labyrinthodon from the Lower Keuper of Cubbington, Warwickshire, described by Huxley in 1859 in the Memoirs Geol. Survey, 'The Warwickshire Coal-field,' p. 56, which may be the same species as that described by Professor Seeley in 1876 in the 'Quart. Journ. Geol. Soc.' under the name of *Labyrinthodon Lavisi*; but our specimen is somewhat larger, and Huxley thought it indicated a jaw two feet in length.

The museum possesses numerous remains of *Stagonolepis Robertsoni* from the Elgin Sandstone of Lossiemouth, specimens which were described by Huxley in the 'Quart. Journ. Geol. Soc.' for 1859 and in the Geol. Survey Monograph, III. : 'Crocodilian Remains found in the Elgin Sandstones.' These remains consist largely of hollow moulds in blocks of

sandstone, and many of the casts made from these are figured in the above-mentioned works.

Other forms that have been described and figured by Huxley in the 'Quart. Journ. Geol. Soc.' for 1869 and 1870, and are preserved in this museum, are *Palæosaurus cylindrodon*, *Teratosaurus* (*Zanclodon*), and *Hyperodapedon Gordoni*.

The remarkable horned reptile *Elginia mirabilis*, from the Triassic sandstone of Cutties Hillock, near Elgin, as well as several species of the Dicynodonts *Gordonia* and *Geikia* from the same locality, described in the 'Philosophical Transactions' for 1893, are represented in the museum by the original casts (taken from the natural moulds in sandstone) which were figured in the plates accompanying the above-mentioned paper. The original sandstone mould of *Geikia* is also here, but the other moulds are in the Survey collection at Edinburgh or in the Elgin Museum.

Two other forms from the Triassic sandstone of Spynie and Lossiemouth, which were described in the 'Philosophical Transactions' for 1894 under the names of *Ornithosuchus Woodwardi*, N., and *Erpetosuchus Granti*, N., are likewise here represented by the original casts from which the figures were drawn, the sandstone specimens themselves being in the British Museum at South Kensington.

Two slabs of footprints from the Elgin Sandstone of Cummingstone, near Elgin, figured by Huxley in the 'Memoir of the Geological Survey,' above mentioned, are also preserved in this museum.

The following is a list of all the species from the Trias (excluding Rhætic) represented in this museum, with the localities from which they were obtained. The figured specimens are indicated, and references are given. F.=Figured; T.=Type.

PLANTÆ.

Name	Formation	Locality
Voltzia	Keuper	Ashley Heath, Market Drayton.
"	Upper Keuper	Pendock, Worcester.
Fucoidal remains	" "	Rowington, Warwick.
Plant remains	Keuper	Bromsgrove.
" "	"	Fulford Quarry, Longton.

CRUSTACEA.

Name	Formation	Locality
Estheria minuta, Alberti	Lower Keuper	Alderley Edge, Manchester.
" "	Keuper	Buttermill Hill, Needwood Forest.
" "	Trias	High House, Warwick.
" "	Upper Keuper	Hill End, 1 mile N.W. of Pendock.
" "	Trias	Morton Bagot.
" "	Upper Keuper	Newent, Gloucester.
" "	" "	Pendock, Ledbury.
" "	" "	Shrewley, Warwick.
" "	Keuper	Fulford Quarry, Longton.

MOLLUSCA.

Name	Formation	Locality
T. *Nucula keuperina*, R.B.N., figured 'Journ. Conch.,' vol. vii. 1894, p. 413.	Upper Keuper	Shrewley, Warwick.
T. *Pholadomya Richardsi*, R.B.N., figured *loc. cit.*, p. 412.	" "	" "

PISCES.

Name	Formation	Locality
Hybodus (*Sphenonchus*) . .	Trias . . .	High House, Warwick.
,, ,, . .	Upper Keuper .	Hill End, 1 mile N.W. of Pendock.
Acrodus keuperinus, Murch. (teeth).	,, ,, . .	Shrewley, Warwick.
,, ,, . .	,, ,, . .	Pendock, Worcester.
,, ,, . .	Trias . . .	High House, Warwick.
,, ,, . .	Upper Keuper .	Moor Court, ½ mile N. of Pendock.
,, (*Hybodus*) *keuperinus* (spines).	Keuper . .	Blagdon, Somerset.
,, ,, ,,	Upper Keuper .	Pendock, Ledbury.
,, ,, ,,	,, ,, .	Shrewley, Warwick.
,, ,, ,,	Keuper . .	Near Frome ?
,, ,, ,,	Upper Keuper .	Moor Court, ½ mile N. of Pendock.
Sagenodus sp. (*Ceratodus*) cast .	Trias . . .	Spynie, Elgin.
Coprolites	Lower Keuper .	Coton End, Warwick.
Palæoniscoid fish . . .	Upper Keuper .	Colwick Wood, Nottingham.
Dictyopyge catoptera, Ag. . .	Bunter . .	Roan Hill, Tyrone.
F. *Semionotus.* Figured by E. T. Newton, 'Quart. Journ. Geol. Soc.,' vol. xliii. 1887, pl. xxii. fig. 8.	Upper Keuper	Colwick Wood, Nottingham.
T. *Dipteronotus cyphus*, Egerton. Type of genus and sp. figured by Egerton, 'Quart. Journ. Geol. Soc.,' vol. x. 1854, pl. xi.	Keuper . .	Bromsgrove.

AMPHIBIA.

Name	Formation	Locality
Labyrinthodont jaw, mentioned by Huxley in 'Mem. Geol. Surv. Warwickshire Coal-field,' p. 56	Lower Keuper .	Subbington, Warwickshire.
Labyrinthodont	Upper Keuper .	Shrewley.
,, (tooth) . .	,, ,, .	Glover's Hill Cutting, Ripple, Worcester.
,, ,, . .	Lower Keuper .	Coton End, Warwick.
,, (scute) . .	Keuper . .	Near Frome ?

REPTILIA.

Name	Formation	Locality
F. *Stagonolepis Robertsoni*, numerous specimens figured by Huxley in the 'Quart. Journ. Geol. Soc.,' vol. xv. 1859, pl. xiv., and in 'Mem. Geol. Surv.,' Monograph III. 'Crocodilian Remains found in Elgin Sandstones.'	Trias . . .	Lossiemouth, near Elgin.
Dinosaurian jaws.	Trias ? . .	Kenilworth.
F. *Palæosaurus cylindrodon*, figured by Huxley, 'Quart. Journ. Geol. Soc.,' vol. xxvi. 1870, pl. iii. fig. 4.	Lower Keuper .	Coton End, Warwick.
F. *Teratosaurus* (*Zanclodon*), figured by Huxley, *loc. cit.*, pl. iii. fig. 11.	,, ,, .	,, ,,
Thecodontosaurus . . .	Keuper . .	Bristol.
F. *Hyperodapedon Gordoni*, figured by Huxley, 'Quart. Journ. Geol. Soc.,' vol. xxv. 1869, p. 145.	Lower Keuper .	Coton End, Warwick.

Name	Formation	Locality
Hyperodapedon Gordoni, mentioned by Huxley, *loc. cit.*, pp. 141, 146, 148	Trias . . .	Otter River, Budleigh Salterton, Devon.
T. *Elginia mirabilis*; Newton.	Trias . . .	Cutties Hillock, Elgin.
T. *Gordonia Traquairi*; "	"	" "
T. " *Huxleyana*; "	"	" "
T. " *Duffiana*; "	"	" "
T. " *Juddiana*; "	"	" "
T. " sp.? "	"	" "

All the above species of *Elginia* and *Gordonia* are represented by the gutta-percha cast from which the figures were drawn. The original moulds in sandstone are either in the Geological Survey Museum at Edinburgh or in the Elgin Museum See 'Phil. Trans.,' vol. clxxxiv. (1893), B, p. 431, pls. xxvi.–xli.

T. *Geikia elginensis*, Newton. The sandstone mould as well as the gutta-percha cast from which the figures were drawn. See 'Phil. Trans.,' vol. clxxxiv. B, 1893, pl. xxxvi.	Trias . . .	Cutties Hillock, Elgin.
T. *Ornithosuchus Woodwardi*, Newton. Cast in gutta percha, from which the drawings were made. The original specimen is in the British Museum at South Kensington. See 'Phil. Trans.,' vol. clxxxv. 1894, B, p. 586, pls. liv.–lvi.	Trias . . .	Spynie, near Elgin.
T. *Erpetosuchus Granti*, Newton. Casts in gutta percha, from which the figures were drawn. The original mould in sandstone is now in the British Museum at South Kensington. See 'Phil. Trans.,' vol. clxxxv. B, 1894, p. 574, pl. liii.	Trias . . .	Lossiemouth, near Elgin.

FOOTPRINTS.

Footprints	Lower Keuper .	Storeton, Cheshire.
Rhynchosaurus	" " .	" "
F. Slabs of footprints of several sizes from less than an inch to nearly 8 inches long. See 'Mem. Geol. Surv.,' Monograph III., pls. xiv., xv., and xxvi., and 'Quart. Journ. Geol. Soc.,' vol. xv. 1859, pl. xiv., figs. 4, 5.	Trias . . .	Cummingstone, near Elgin.

III. *List of British Triassic Fossils in British Museum.* *By* Dr. A. Smith Woodward, *F.R.S., F.G.S., F.Z.S.*

REPTILIA.

Erpetosuchus Granti . .	E. T. Newton, 'Phil. Trans.,' vol. clxxxv. B, 1894, p. 574, pl. liii. Impressions of skull and portions of the skeleton, the type specimens (R. 3,139) from the Trias of Lossiemouth or Spynie, near Elgin.
Hyperodapedon Gordoni .	Huxley, 'Quart. Journ. Geol. Soc.,' vol. xv., 1859, p. 435.

Hyperodapedon Gordoni .	Skull and skeleton (R. 699) described by Huxley in 'Quart. Journ. Geol. Soc.,' vol. xliii. p. 675, pl. xxvi., woodcuts 1 and 4; also Burckhardt, 'Geol. Mag.,' 1900, pp. 486 and 529.
	Portions of mandible (R. 3,138) figured by Huxley, *op. cit.*, figs. 7 and 8.
	Fragments of skull (R. 3,137) noticed by Huxley in 'Quart. Journ. Geol. Soc.,' vol. xxv., 1869, figs. 7 and 8.
	Portions of skull (R. 3,140) described and figured by Boulenger in 'Phil. Trans.,' vol. cxcvi. B, 1903, p. 175, pl. xi. Portions of skeleton (R. 3,148).
	From the Trias of Lossiemouth, near Elgin.
Ornithosuchus Woodwardi .	E. T. Newton, 'Phil. Trans.,' vol. clxxxv. B, 1894, p. 586, pls. liv.–lvi.
	Skull and portions of skeleton, the type specimens (R. 2,409, 2,410). Portions of skeleton (R. 3,142), some figured by Boulenger in 'Phil. Trans.,' vol. cxcvi. B, 1903, pl. xv. Portions of skull and skeleton (R. 3,143) figured by Boulenger, *tom. cit.*, pl. xiv.
	? Portions of skull and skeleton (R. 3,149) Trias of Spynie, near Elgin.
Rhynchosaurus articeps .	Owen, 'Trans. Camb. Phil. Soc.,' vol. vii. 1842, p. 355.
	Skull and parts of mandible (R. 1,236) described and figured by Huxley in 'Quart. Journ. Geol. Soc.,' vol. xliii. 1867, p. 689, pl. xxvii., fig. 1, and woodcuts 2 and 5.
	Portions of skeleton of same individual as last (R. 1,238). Right pes fig. by Huxley, *loc. cit.*, pl. xxvii., fig. 5. Portion of skeleton (R. 1,239) figured by Huxley, *loc. cit.*, pl. xxvii., figs. 2–4. Palatal portion of skull (R. 1,237). Caudal region (R. 1,240). Limb (R. 1,241). From the Keuper of Grinshill, Shropshire.
Stenometopon Taylori . .	Boulenger, 'Phil. Trans.,' vol. cxcvi. B, 1903, p. 178, pls. xii. and xiii.
	Skull and portions of skeleton, type specimens. Trias of Lossiemouth, near Elgin.
Stagonolepis Robertsoni .	Agassiz, 'Recherches sur les Poissons Fossiles du Vieux Grès Rouge,' 1844, p. 139.
	Numerous impressions of scutes and some fragments of bone. Trias, Lossiemouth, near Elgin.
Telerpeton elginense . .	Mantell, 'Quart. Journ. Geol. Soc.,' vol. viii. 1852, p. 100.
	Skeleton (R. 3,136) described and figured by Huxley in 'Quart. Journ. Geol. Soc.,' vol. xxiii. 1867, pp. 77–84, text figures A–E.
	Also Boulenger in 'Proc. Zool. Soc.,' vol. i. 1904 (not yet published). Skull and skeleton (R. 3,144) described by Boulenger, *tom. cit.* Imperfect skull (R. 3,147) described by Boulenger, *tom. cit.* Trias, Lossiemouth, near Elgin.

LABYRINTHODONTIA.

Capitosaurus stantonensis .	A. S. Woodward, 'Proc. Zool. Soc.,' 1904, vol. ii. (not yet published). Preliminary notice by J. Ward, 'Trans. N. Staffs Field Club,' Feb. 22, 1900, pls. iv. and v.
	Type. A skull from the Lower Keuper of Stanton, near Norbury, North Staffordshire.

Capitosaurus stantonensis . The block of sandstone containing the skull was split along the plane of the cranial roof, leaving most of the roof bones adherent to one slab, while the impression of these with the rest of the skull remained in the counter-part slab, as shown by the photograph (plate vi.). The skull is distinguished from that of all known species of the genus by the shape of the occipital border and auditory notches, as also by other characters.

PISCES.

Acrodus (?) keuperinus . . (Murchison and Strickland.) A. S. Woodward, Catal. Foss. Fishes, B.M., pt. i., 1889, p. 281, pl. xiii., figs. 1 and 2; 'Ann. Mag. Nat. Hist.' (6), vol. iii. 1889, p. 297, pl. xiv., figs. 1–3, and *loc. cit.*, vol. xii. 1893, p. 283, pl. x., fig. 5.
Teeth and dorsal fin-spines and cephalic spines from Upper Keuper of Pendock, Ripple, and Burgehill, Worcestershire; from Shrewley and Rowington, Warwickshire.

Ceratodus lævissimus . . L. C. Miall, Siren. and Crossopt. Ganoids, pl. i. ('Pal. Soc.,' 1878), p. 32, pl. v., fig. 2; A. S. Woodward, 'Ann. Mag. Nat. Hist.' (6), vol. xii. 1893, p. 282, pl. x., fig. 1.
Two teeth, the type from Upper Keuper of Ripple, Worcestershire; the other from Lower Keuper of Coton End, Warwick.

Dictyopyge catoptera . . (Agassiz.) R. H. Traquair, 'Quart. Journ. Geol. Soc.,' vol. xxxiii., 1877, p. 567. *Palæoniscus catopterus*, Agassiz, 'Poiss. Foss.,' vol. ii., pt. i., p. 303 (name only), and Egerton, 'Quart. Journ. Geol. Soc.,' vol. xiv., 1858, pl. xi., fig. 4.
Shoals of fishes from Keuper, Roan Hill, Tyrone.

Dictyopyge superstes . . (Egerton.) K. A. von Zittel, 'Handb. Palæont.,' vol. iii., 1887, p. 203. *Palæoniscus superstes*, Egerton, 'Quart. Journ. Geol. Soc.,' vol. xiv. 1858, p. 164, pl. xi., figs. 1–3.
Type: A fish from Upper Keuper of Rowington.

Phœbodus Brodiei . . A. S. Woodward, 'Ann. Mag. Nat. Hist.' (6), vol. xii. 1893, p. 282, pl. x., figs. 2–4.
Type: Teeth from Upper Keuper of Shrewley, Warwickshire.

Semionotus Brodiei . . E. T. Newton, 'Quart. Journ. Geol. Soc.,' vol. xliii. 1887, p. 538, pl. xxii., figs. 1–8.
Type: Imperfect fishes from Upper Keuper of Shrewley, Warwickshire.

CRUSTACEA.

Estheria minuta . . . (Alberti.)
From Keuper of Alderley Edge, Cheshire; Shrewley, Warwickshire; and Pendock, Worcestershire. Also from 'Trias near Shrewsbury.'

MOLLUSCA.

Thracia (?) Brodiei . . R. B. Newton.
Pholadomya (?) Richardsi . R. B. Newton.
Nucula keuperina . . R. B. Newton.
Type specimens presenting a marine facies, described by R. B. Newton, 'Note on some Molluscan Remains lately discovered in the English Keuper,' 'Journ. Conchology,' 1894, vol. vii. p. 408.

Nucula keuperina . . .	From Upper Keuper, Shrewley, Warwickshire, associated in the matrix with *Acrodus keuperinus* and *Estheria minuta*.

PLANTÆ.

Carpolithes, sp. . . .	Seward, 'Catalogue Mesozoic Plants,' B.M., pt. iv. 1904, p. 7. From Keuper of Longdon and Rowington, Warwickshire. Also indeterminate fragments of Coniferæ from Keuper of Rowington and Leicester.

Edenvale Caves, Co. Clare.—Final Report of the Committee, consisting of Dr. R. F. SCHARFF (*Chairman*), Mr. R. L. PRAEGER (*Secretary*), Mr. G. COFFEY, Professor G. A. J. COLE, Professor D. J. CUNNINGHAM, Mr. G. W. LAMPLUGH, Mr. MCHENRY, *and* Mr. R. J. USSHER, *appointed to explore Irish Caves. (Drawn up by the Chairman.)*

SINCE our last report was submitted to the British Association, Mr. Ussher has completed the excavations of the extensive caves of Edenvale, co. Clare, and sent altogether a collection of more than 50,000 bones to be named. Besides these there were flints and implements used by primitive man and relics of various periods on which it is proposed to submit a detailed report to the Royal Irish Academy during next winter.

Mr. Ussher has explored other districts of Ireland with the view to continuing the cave researches, but this Committee do not propose to apply for a further grant.

The Edenvale remains have not been fully determined, but so far they have yielded the following species :—

Man . . .	(*Homo sapiens*)	Arctic Lemming.	(*Dicrostonyx torquatus*)
Bats . . .	(Several species)	Domestic Ox .	(*Bos taurus*)
Hedgehog .	(*Erinaceus europæus*)	Domestic Sheep .	(*Ovis aries*)
Domestic Cat	(*Felis domestica*)	Domestic Goat .	(*Capra ægagrus*)
Wild Cat .	(*Felis caligata*)	Domestic Pig .	(*Sus scrofa domestica*)
Dog . . .	(*Canis familiaris*)	Wild Pig .	(*Sus scrofa ferus*)
Fox . . .	(*Vulpes alopex*)	Red Deer .	(*Cervus elaphus*)
Irish Stoat .	(*Putorius hibernicus*)	Giant Deer .	(*Megaceros giganteus*)
Marten .	(*Mustela martes*)	Reindeer .	(*Rangifer tarandus*)
Bear . .	(*Ursus arctos*)	Horse .	(*Equus caballus*)
Badger .	(*Meles taxus*)	Birds . .	(Many species)
Arctic Hare .	(*Lepus timidus*)	Frog . .	(*Rana temporaria*)
Rabbit .	(*Lepus cuniculus*)	Fishes .	(Several species)
Irish Rat .	(*Mus hibernicus*)	Land Mollusca .	(Many species)
Field-mouse .	(*Mus sylvaticus*)		

The Influence of Salt and other Solutions on the Development of the Frog.—Report of the Committee, consisting of Professor W. F. R. WELDON (*Chairman*), Mr. J. W. JENKINSON (*Secretary*), *and* Professor S. J. HICKSON. *(Drawn up by the Secretary.)*

THE object of this investigation is to discover whether the distortion of development, or monstrosity, produced by growing the eggs of the frog in a certain concentration (about 0·6 per cent.) of common salt solution is due to the physical—increased osmotic pressure—or chemical properties of the solution, or both.

The monstrosity consists in (1) the failure of the blastopore to close, so that a large persistent yolk-plug is produced; and (2) the failure of the medullary folds to close either (α) throughout, or (β) partially, generally in the region of the brain, so that a sort of anencephalous monster results.

With this object the eggs have been grown in solutions whose concentration is isotonic with that of a 0·625 per cent. solution of sodium chloride, of the following substances:—

(1) Chlorides of potassium, lithium, ammonium, calcium, magnesium, barium, strontium;

(2) Bromides of these seven bases and of sodium;

(3) Iodides of sodium, potassium, lithium, and ammonium;

(4) Sulphates of sodium, lithium, ammonium, and magnesium;

(5) Nitrates of sodium, lithium, ammonium, potassium, magnesium, strontium, and calcium;

(6) Cane sugar and dextrose;

(7) Urea.

The external characters of the embryos produced in these solutions have been determined; the microscopical examination of sections is in progress. The results obtained, as far as they can at present be stated, are these. The effects produced by the above solutions on the development of the frog may be divided into four classes:

I. *Chlorides of ammonium, strontium, barium, calcium; bromides of ammonium, strontium, barium, calcium, and magnesium; iodides of lithium, ammonium, and potassium; nitrates of ammonium, calcium, and strontium.*

In all these the egg dies at a comparatively early stage, sometimes during segmentation, sometimes when the dorsal lip of the blastopore has just appeared; occasionally a very irregular circular lip may be completed.

The large yolk-cells seem to be affected first, the small animal cells continuing to divide for some time; but as the normal overgrowth of cells at the lip of the blastopore is prevented, the roof of the segmentation cavity is thrown into folds and wrinkles. Mesoderm cells are formed at the equator of the egg, but thrown into the segmentation cavity.

Ultimately all the cells and their nuclei undergo disintegration and degeneration: they are found lying in a coagulum—easily visible to the naked eye—produced by the fusion and liquefaction of yolk-granules. It seems possible that the salts enter the tissues and there form with the carbonic acid given off by the cells insoluble carbonates, as bubbles are given off when the eggs are placed in hydrochloric acid.

II. The egg loses its power of elongating in the direction of the longitudinal axis of the embryo, that is, remains spherical or nearly so; differentiation of the germ-layers and of the organs of the embryo proceeds nevertheless.

This effect is produced by *chlorides of potassium and lithium, bromides of sodium, potassium and lithium, iodide of sodium, sulphates of lithium and ammonium, and nitrates of lithium and potassium.*

In all these a large circular blastopore is formed enclosing a correspondingly large yolk-plug. This yolk-plug is only very slowly withdrawn, if at all. The medullary folds may or may not close. There is variation in this

respect not only between embryos grown in different solutions, but even between those grown in one and the same medium. There is a spacious bilateral archenteron extending in front of the dorsal lip of the blastopore.

The mesoderm is formed in the usual manner, partly from cells in the neighbourhood of the blastoporic lip, partly by differentiation of yolk-cells which have been pushed into the segmentation cavity. This cavity is obliterated.

The notochord is not formed in quite the normal fashion, that is, by the splitting off of a rod of cells from the roof of the archenteron. Its formation in these monsters recalls the mode of its origin in the Urodela, Gymnophiona, and Petromyzon; a median strip of the whole thickness of the roof of the archenteron is folded off, while cells from the sides grow beneath this to complete the definitive roof of the gut.

The following organs are formed, though their development is often abnormal; as, for example, when the cavity of the optic vesicle is reduced to a narrow slit:—

The suckers; the optic vesicles, but not the lens; the auditory vesicle; the infundibulum; the pituitary body; the neural crest, with the vagus and trigeminus ganglia; the protovertebræ; a trace of the splanchnocœl; the liver diverticulum.

Normal histological differentiation may set in, for example, in the cells of the suckers and of the notochord.

The notochord seems to retain its capacity of growth in the direction of its long axis; it becomes bent and twisted in both a vertical and a horizontal plane.

Ultimately degeneration and disintegration of the embryonic tissues sets in. The parts most commonly affected first are the medullary groove (or tube), the lips of the blastopore (when this has not closed), and the general ectoderm. Later the yolk-cells become altered and die.

These changes are as follows:—

(1) Grey degeneration, seen usually in the medullary groove. The cells protrude above the surface; the pigment retreats to the inner end, leaving the cells white; the cells fall out.

(2) Wrinkling and pitting of the surface. The ectoderm is thrown into folds; the cells are cast out.

(3) Liquefaction of the yolk-cells by fusion of yolk-granules.

This cellular disintegration is accompanied by degeneration of the nuclei.

It is a common occurrence for these dying embryos to become constricted into two parts, one portion being pushed bodily through the vitelline membrane into the jelly as an ex-ovate.

III. The embryo is able to elongate, but development is abnormal, particularly in the closure of the blastopore and medullary folds.

Degeneration and death eventually follow.

(*a*) *Sodium chloride and sodium nitrate.*

There is a large persistent yolk-plug.

The medullary folds fail to close, most frequently in the region of the brain. The floor of the medullary groove here undergoes the process of

grey degeneration already referred to. The lips of the blastopore are often similarly affected.

The yolk-cells in the interior degenerate and liquefy; the liquefied mass may burst through the ectoderm and spread over the surface. In spite of this, differentiation of the organs of the body proceeds until the embryo dies.

Suckers, gills, tail (often double), pituitary body, optic vesicles, lens, infundibulum, auditory vesicle, neural crest with the vagus and trigeminus ganglia; protovertebræ, pronephric thickening, and liver diverticulum are all formed.

The notochord is formed in the same abnormal way as described under II., and is bent and twisted.

(β) *Magnesium chloride, magnesium sulphate, and magnesium nitrate, cane sugar and dextrose.*

The blastopore closes, though slowly; the medullary folds do not.

In the magnesium salts the brain alone remains open; in the sugars the entire length of the medullary folds. The exposed part in all cases undergoes grey degeneration.

All the organs mentioned under (α) are developed, and in addition the pericardium, together with a few endocardial cells.

The tail is better developed and the embryos longer.

IV. Development is nearly or quite normal; *urea and sodium sulphate.*

In the former the blastopore and medullary folds close, though more slowly than usual.

The organs already referred to are all formed; in addition, the heart and pericardium, the pronephros, the splanchnocœl, the dorsal aortæ and posterior cardinal and vitelline veins, and the subnotochordal rod.

The notochord, though arising in the abnormal fashion observed in other cases, has well-differentiated, vacuolated cells. The myotome cells are elongate and multinucleate.

Eventually the embryos die.

The cells of the central nervous system and of the ectoderm degenerate.

Mesoderm and yolk-cells swell up; the latter indeed often produce a hernia-like ventral swelling behind the liver, subsequently bursting through the body-wall at this point.

In *sodium sulphate,* on the other hand, development appears to be perfectly normal, and to proceed at the normal rate. The tadpoles will live in the solution for many weeks.

As the work is still incomplete it would be premature to offer any explanations or conclusions. At the same time it may be pointed out that the facts seem to contradict Bataillon's assertion that the distorted development of the sodium chloride monster is solely the effect of the increase in the osmotic pressure. More probably the phenomena are to be attributed to the poisonous properties of the substances employed, even in the case of the sugars, the differences being due to differences in the permeability of the tissues of the embryo.

The Committee ask to be reappointed in order that the microscopical investigation may be brought to a satisfactory conclusion.

The Probability of Ankylostoma *becoming a Permanent Inhabitant of our Coal Mines in the event of its introduction.—Interim Report of the Committee, consisting of* Dr. G. H. F. NUTTALL (*Chairman*), G. P. BIDDER (*Secretary*), Dr. A. E. BOYCOTT, Dr. J. S. HALDANE, *and* A. E. SHIPLEY.

SUMMARY.

THERE are many channels by which *Ankylostoma* might be introduced into British coal-mines.

The conditions found underground in these mines are such that the worm would, in many cases, at any rate, probably become firmly established.

In view of the expense and difficulty of eradicating the worm from any mine in which it has become established, it is of the greatest importance that preventive measures should be undertaken without delay. Complete eradication does not yet appear to have been ever accomplished.

The necessary prevention is best accomplished by the provision of proper sanitary accommodation in the main roads underground and at the pit's mouth, by regulations to prevent pollution of the pit by human fæces, and by the establishment of a limited quarantine system for work-people from infected areas, with compulsory notification of cases to the Home Office.

Importance of the Question.

The economic importance of *Ankylostoma* is very great. In many tropical countries it is one of the chief causes of death ; thus in Porto Rico more than one-fifth of all deaths are due to this worm disease. In this country the underground workings of mines afford the necessary tropical conditions of temperature, and in this way provide situations in which the worm is capable of flourishing. In the Westphalian coalfield the disease became prominent about four years ago, and many cases of illness occurred. The number of men who were thus incapacitated from work was observed to be increasing rapidly ; in consequence very extensive efforts have been made to stamp out the disease. Hospitals were built, a special staff of doctors provided, all the men were specially examined ; those who were found to be infected were not allowed to work underground, and were all treated in the hospitals until they were free from the worm. It is impossible to state exactly even the direct expense of all these measures, but the figure certainly amounts to several hundred thousand pounds.

When it is remembered that 650,000 men are employed underground in the coal-mines of Great Britain, and that it has been found that in a badly infected mine 80 per cent. of the men may have the disease, the gravity of the question is apparent. By the incidence of such an epidemic both employers and workpeople must be seriously affected, not only in the measure of the number of men seriously ill, but also of the far greater number who have no obvious symptoms, but an impaired efficiency for work.

The sanitary arrangements in Westphalia have been carried out very

thoroughly and energetically, but it has not been found possible *completely* to eradicate the worm. The number of infected men has been greatly reduced, but a small percentage remains who still harbour the worm. This small percentage remains about the same in spite of the continuance of treatment, and is, of course, always capable of introducing the disease into any fresh mine or of reinfecting the mine to any extent if preventive measures were relaxed.

Before considering the probability of the spread of *Ankylostoma* in this country it is necessary to point out that we have hardly any definite information as to its complete absence at the present time. Only one case of the disease has been recorded in a British coal-mine, but the worm may well be present to a limited degree without causing obvious illness. A latent infection of this kind, owing to some small change in the temperature or the moisture of a mine, may increase to a serious epidemic at any time, or may be carried to other pits where more favourable conditions may lead to the most disastrous results. No evidence of the presence of the worm has been found in the few collieries which have been systematically examined, but it must not be assumed too readily that it is completely absent.

Is there a Probability of Ankylostoma *becoming established in British Coal-mines ?*

(A) *Possible Sources of Infection.*

(1) The worm is endemic among the general population in nearly all tropical and sub-tropical countries (Southern Asia, Africa, South America, West Indies, &c.) and parts of North America, Australia, and in Europe south of the Alps, and in Hungary.
(2) It is present among underground workers in the Westphalian coalfield and in the French and Belgian coal-mines.
(3) It is present in the Cornish tin-mines, at any rate in the Camborne district.

The infection may thus be easily introduced into this country from the tropics and Southern Europe by returned miners, or even by those who have not followed any underground employment abroad (soldiers, navvies, &c.); and from Germany, Belgium, France, and the Cornish mines by underground workers. Cases have been recorded in Lanarkshire and in Belfast in the persons of soldiers, and in the former case a man was actually working as a miner when his illness attracted attention. A large number of Poles are employed in the Lanarkshire coalfield, some of whom may have worked in Westphalia or Hungary, and Italians have lately been introduced into a metalliferous mine in the North of England.

(B) *Conditions found underground in British Coal-mines which would influence the establishment of the Worm.*

The conditions of temperature on the surface are such that practically the worm cannot spread among the ordinary population in this country. In summer the eggs may hatch and the larvæ develop to the infective stage in the open air, but any small danger which might arise from this source is rendered negligible by the almost universal use amongst all classes in this country of arrangements for the proper disposal of excreta.

In underground workings, however, the temperature, &c., are frequently such that the eggs will quickly hatch and the larvæ develop; there are very seldom any 'sanitary arrangements,' and the darkness renders it difficult to avoid coming into contact with fæcal material.

(1) *Temperature.*—There is need of much more collected information respecting the actual temperatures found in coal-mines. It would, however, appear that a temperature of 70° F. or more is found in parts of most pits, while temperatures of 80° F. are not uncommon.

The eggs may hatch and the larvæ reach the encapsuled stage at any temperature from 60° F. to about 95°–100° F.; the optimum temperature seems to be about 75°–80°. Below 60° the eggs may occasionally hatch, but the larvæ will not grow to the infective stage.

Once the larvæ have reached the infective stage they seem to be largely indifferent as to temperature: they certainly live longer at room temperature than at 98°, but not longer than at about 70° F.

(2) *Moisture.*—Some water is to be found about all mines; even if there is very little standing water in the roads there is enough to produce a muddy condition at places. The worm cannot be propagated in complete absence of moisture, and the larvæ are soon killed by drying; but parts, at any rate, of most mines are sufficiently wet to allow the larvæ to grow freely.

On the other hand there may be too much water to allow the eggs to hatch. Eggs contained in fæces covered with a shallow layer of water will not produce larvæ at any temperature. Once hatched, however, the larvæ flourish in water.

(3) *Filth.*—Coal-mines appear to be a good deal cleaner, from a sanitary point of view, than metalliferous mines. This is in part due to the fact that at the face fæces are generally deposited in the goaf [1] and covered with coal dust; and in part to the greater prevalence of dust and to the larger area.

There is, however, no failure of sufficient fæcal contamination. In many instances small partly disused roads are made use of by the men for the purpose of relieving their bowels. This usage is particularly dangerous.

Duration of the Infection in Man.

Well-authenticated cases of infection, lasting more than six years after the last possible contact with infected materials, have been recorded.

Viability of the Worm in Mines.

Encapsuled larvæ have lived in the Gordon Laboratory for twelve months (still alive) at 68° F. There is no direct evidence as to how long they may live underground, but in water obtained from two North Staffordshire mines they suffered no ill effect, and were observed for several weeks.

Natural Conditions in Mines which are unfavourable to the Worm.

Parts of all, and nearly the whole of some mines, fail to produce the combination of dampness and warmth favourable to the hatching of eggs.

[1] The 'goaf' or 'gob' is the worked part of a mine, where the coal has been removed. The supporting timbers are withdrawn, and the roof is allowed to close on to the floor.

But if the eggs cannot hatch in certain parts which are too cool, the larvæ can be brought to these parts either on the boots, &c., or by the flow of water.

There is no evidence to show that any substance in the coal is deleterious to the worm, though weathered coal might contain such products. If the water is salt (as it is at Levant Mine) protection seems to be secured; but traces of the heavy metals (iron, copper) do not seem to be harmful.

Nothing is known of any natural enemies. In some mines the fæcal deposits, wood, &c., show an abundant fauna, most commonly dipterous larvæ and small nematodes other than *Ankylostoma.*

It might be supposed that in the case of a species in which a single female produces millions (probably many millions) of eggs some specific enemy would have been developed—some organism whose special characters enabled it to live on the highly nutritious contents of the eggs, or on the newly hatched larvæ. But if such a hostile species has been evolved it is in the tropical and sub-tropical home of *Ankylostoma* that it should be sought for, not in the temperate zone. In the mud of a British coal-mine the limited number of species of animals and plants are either from the surface above, or have been brought with the timber from uninfected countries. It is possible, therefore, that in a warm and moist coal-mine in Great Britain the conditions are actually more favourable to the uncontested life of the larvæ than even in the tropics. It would not be out of harmony with any known facts to suppose that a single pair of worms might give rise in one generation to a progeny equal in number to the population of the British Islands.

(C) *Preventive Measures.*

(a) *In non-infected mines.*

1. A sufficient supply of sanitary pails, combined with a rigid system of inspection and cleaning, is all that is necessary if the use of these conveniences can be enforced. The habit of defæcating underground at all should be discouraged as much as possible: much may be done in this way by providing proper and well-looked-after accommodation at the pit's mouth. In dry mines the fæces can probably be safely disposed of by burying them under coal dust in the goaf; but in all cases permanent roads and stations should be provided with conveniences.

2. Examination of fresh hands. All men applying for work who have ever worked in tropical or South European countries, or in mines where the worm is known to be present, should be rejected till it is shown that they do not harbour the worm. It is useless doing this unless their state of health is entirely disregarded; it is of no moment whether they are or have been ill or not, since perfectly healthy persons may carry the worm and be capable of infecting a mine. Some sort of quarantine list should be made. At the present it would include Cornwall, Westphalia, the French and Belgian coalfields, South European and all tropical countries.

3. Reduction of temperature and moisture is difficult, in most cases quite impracticable, and not necessary if proper sanitary and quarantine regulations are made and carried out. Any reduction in the moisture is, moreover, not unattended with danger from explosions.

There should be no difficulty in introducing a proper system of

sanitary accommodation if the genuine sympathy of both the mine owners and the men's representatives could be secured. The additional expense in providing and looking after the pails, &c., would be relatively small, and in the larger pits should be practically inappreciable. In an English colliery employing 2,000 underground hands the excreta from the men on the working roads have for the last four years been disposed of by the use of 100 movable pans, emptied on the spoil-heap once a week and recharged for use with coal dust and a disinfectant fluid. The total cost is found to come to about 1*l.* a week, and it is stated that the fouling of the roads has now ceased.

The number of hands which it would be necessary to examine individually would never be large. There is no need to examine men who live in England and are fresh to mining, or who have worked in a mine which is known to be free from the worm. In most English coalfields these would include the great majority of the men. The method of examination by means of blood-films affords a fairly satisfactory method to which the men have no objection. It seems probable that many medical officers of mines are not competent to undertake the necessary investigations; there would, however, be no difficulty in making arrangements with pathological and public-health laboratories such as have been established in many parts of England. It is only in accordance with the general policy of the country as to public health that the expenses of such examinations should be provided, in part at least, out of public funds.

(b) *In infected mines.*

The conditions here are altogether different, and may require the most drastic and expensive measures of universal examination and treatment combined with anything that may be practicable in the way of cooling, drying, and disinfecting the mine. The great efforts made on the Continent thoroughly to disinfect infected mines, and their partial success, have been referred to in our opening paragraphs. Particulars will be found in the Blue Books and other recent publications dealing with the subject.[1]

There is no evidence as yet of any natural process which would cause *Ankylostoma* to disappear from a mine in which it had once found a home. Total desertion of the mine by human beings would presumably have this effect, but it would appear necessary that such desertion should last not less than a year. And from the experience of the Westphalian and other European coalfields it would appear probable that, if *Ankylostoma* should ever thoroughly take possession of one of the many warm and moist British coal-mines, it will not be eliminated except by the invention of even more efficient disinfection than the drastic and expensive processes enjoined on the coal-masters by the German Government.

[1] See, inter alia, *Parliamentary Paper* [Cd. 1671], 1903 and [Cd. 1843] 1903; special supplement to the *Colliery Guardian*, November 6, 1903; Boycott and Haldane in the *Journal of Hygiene*, vol. iii. p. 95; vol. iv. p. 73; Boycott, *ibid.* p. 437.

Occupation of a Table at the Marine Laboratory, Plymouth.—Report of the Committee, consisting of Mr. W. GARSTANG (*Chairman and Secretary*), Professor E. RAY LANKESTER, Mr. A. SEDGWICK, Professor S. H. VINES, *and* Professor W. F. R. WELDON.

MISS IGERNA SOLLAS, of Newnham College, Cambridge, occupied the British Association's table at the Plymouth Laboratory from September 1 to September 29, 1903, during which period she carried out an investigation on the development of spicules in *Amphiura elegans.*

Mr. W. Woodland, B.Sc., of University College, London, applied for the use of the Association's table at Plymouth in the spring of the present year. This application could not be granted, owing to the fact that in the absence of the usual grant of money the Committee had no power to nominate to the table for more than one month in the year, the period for which the British Association has the right of nomination as a 'Founder' of the Marine Biological Association.

By the kindness of Dr. Allen, Director of the Plymouth Laboratory, Mr. Woodland was, however, accommodated at the Laboratory gratuitously during April, where he carried out a further investigation on the development of spicules in Echinoderms, more particularly in *Echinus esculentus* and *Thyone.*

The Committee ask to be reappointed with a grant of 10*l.*, in order that they may be in a position to appoint competent investigators to work at the Plymouth Laboratory for at least three months in the year.

Index Generum et Specierum Animalium.—Report of the Committee, consisting of Dr. H. WOODWARD (*Chairman*), Dr. F. A. BATHER (*Secretary*), Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, *and* Dr. W. E. HOYLE.

THE recording of literature by Mr. C. Davies Sherborn has proceeded regularly, though more slowly. The purchase of rare books has been continued in a most satisfactory manner. These, after serving the recorder's purpose, are invariably offered first to the Trustees of the British Museum. If not purchased by them, care is taken that they shall be purchased by some other public library, so as to be available to students for the future. In this way a small fund has been long maintained for acquiring otherwise inaccessible volumes, and the Association grant is left free for the actual work.

The enormous number of *nomina nuda* met with in the literature between 1801–1850 involves a vast amount of labour, uninteresting, but none the less necessary, seeing that one of the chief objects of this index is to enable the student to find any name, whether valid or invalid, of which he is in search. The extent of the undertaking may be inferred from a single example. It appears that Dejean, the coleopterologist, is responsible in his catalogues for no fewer than 22,399 names, every one of which has to be recorded and checked, not only with four editions of his own work, but also with the diagnoses and names of his contemporaries and later authors.

The Committee have to report with deep regret the death of Mr. Robert McLachlan, a colleague who followed the work with the keenest interest.

The Committee desire to be reappointed, with the addition of the name of the Hon. Walter Rothschild, who has kindly consented to serve, and urgently press for a further grant of 100*l.*, so that more rapid progress may be possible.

The Zoology of the Sandwich Islands.—Fourteenth Report of the Committee, consisting of Professor NEWTON (*Chairman*), Mr. DAVID SHARP (*Secretary*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Dr. P. L. SCLATER, Dr. F. DU CANE GODMAN, *and* Mr. EDGAR A. SMITH.

THE Committee was appointed in 1890 and has since been annually reappointed.

Since the last report, Vol. III., Pt. 4, of the 'Fauna Hawaiiensis' has been published by the Committee, and also the part dealing with Vertebrata, by Mr. Perkins, mentioned in the last report.

The Microlepidoptera have been studied by Lord Walsingham, and it is expected that his report on them will shortly be completed. Some further progress has been made with the examination of the Coleoptera, but the working out of this Order of Insects still remains a difficulty.

The Committee asks for reappointment without a grant.

Coral Reefs of the Indian Region.—Fifth Report of the Committee, consisting of Mr. A. SEDGWICK (*Chairman*), Mr. J. STANLEY GARDINER (*Secretary*), Professor J. W. JUDD, Mr. J. J. LISTER, Mr. FRANCIS DARWIN, Dr. S. F. HARMER, *and* Professors A. MACALISTER, W. A. HERDMAN, *and* S. J. HICKSON.

THE Committee have received the following report from Mr. Stanley Gardiner, who has had charge of the work:—

During the year two parts of 'The Fauna and Geography of the Maldive and Laccadive Archipelagoes' have been published, viz. Parts II. and III. of Vol. II. They contain reports by Mr. Edgar Smith, on the Marine Mollusca; Mr. R. C. Punnett, on the Enteropneusta; Mr. L. A. Borradaile, on various Crustacea; the Rev. T. R. R. Stebbing on the Isopoda; Mr. E. T. Browne, on the Hydromedusæ; Mr. Forster-Cooper, on the Antipatharia; Mr. R. I. Pocock, on the Arachnida; and by Mr. Stanley Gardiner, on the Variation of the Madreporaria and the Astraeidæ.

Part IV., completing Vol. II., is in hand, and will contain among others, papers by Professor S. J. Hickson, on the Gorgonians and Pennatulids; Professor Coutière (of Paris), on the Alphaeidæ (about seventy species); Surgeon-Major Alcock, on the Paguridæ; Mr. L. A. Borradaile, on the Hydroids; Mr. A. O. Walker, on the Amphipoda; Mr. A. E. Shipley,

on the Parasites; and Mr. J. Stanley Gardiner, on the remainder of the Madreporaria.

Papers are also expected from Dr. Hoyle, on the Cephalopoda; Dr. Norris Wolfenden, on the Copepoda; Mr. Forster-Cooper, on the Pteropoda; Professor Topsent (of Rennes), on the Sponges, &c.

It is proposed to summarise the zoological results in respect to the distribution of marine animals in a Supplementary Part, to be issued in 1906, when the accounts of certain other groups will have been published. This will be sent gratis to subscribers. The seven parts of the Fauna and Geography already published form a sufficient guarantee that the work will be properly completed, and the Committee consider that they may now be dissolved.

Madreporaria of the Bermuda Islands.—Report of the Committee, consisting of Professor S. J. Hickson (*Chairman*), Dr. W. E. Hoyle (*Secretary*), Dr. F. F. Blackman, Mr. J. S. Gardiner, Professor W. A. Herdman, Mr. A. C. Seward, Professor C. S. Sherrington, *and* Mr. A. G. Tansley, *appointed to conduct an investigation into the Madreporaria of the Bermuda Islands.*

The Committee report that they have been in communication with the authorities of the Bermuda Biological Station for Research, and have been in readiness to co-operate should an opportunity have arisen. They regret, however, that such has not been the case, as no naturalist from this country has applied for facilities to work in the Bermudas.

Dr. J. E. Duerden, who hoped to have been able to undertake this work, found himself unable to do so. The Committee suggest that they should be reappointed, but do not ask for a grant.

Colour-physiology of the Higher Crustacea.—First Report of the Committee, consisting of Professor S. J. Hickson (*Chairman*), Dr. F. W. Gamble (*Secretary*), Dr. W. E. Hoyle, *and* Mr. F. W. Keeble, *appointed to enable Dr. F. W. Gamble and Mr. Keeble to conduct Researches in the Colour-physiology of the Higher Crustacea.*

During the present summer Messrs. Gamble and Keeble have completed a further spell of work on the colour-physiology of the higher crustacea. By the aid of the grant allotted to this research, apparatus has been bought for the experimental investigation of the chromatophores and their contained pigments and fats in *Hippolyte varians*; but as the most suitable apparatus has only lately been found after a series of trials, the present Report is of an interim and not of a final nature.

But although the work is still proceeding, Dr. Gamble reports as follows on the results obtained up to the present time. The apparatus has been set up in Mr. Keeble's laboratory at Trégastel, Côtes-du-Nord, France, with a view of determining (i) the influence of light and darkness on the development of the pigments of *Hippolyte*; (ii) the comparative susceptibility of *Hippolyte* at different periods of life; (iii) the origin and

significance of the chromatophoric fat discovered and described by Messrs. Keeble and Gamble.

The results of this year's investigations, incomplete as they are, show (i) that starting with the almost colourless (*i.e.*, adolescent) stage with which *Hippolyte* begins its colour-history, continued darkness induces the formation of red pigment even in the absence of food; a conclusion that has bearings of considerable interest in relation to deep-sea and Arctic crustacea.

(ii) Further, the colourless stage is one of great susceptibility. By appropriate coloured screens, a green or brown tint is rapidly induced; whereas, in adults, the pigmentary system gives way far less readily. This susceptibility explains to a large extent the way in which *Hippolyte* grows into its surroundings.

(iii) Finally, the origin and fate of the chromatophoric fat has been tested by a couple of experiments. The results are not yet completely worked out, and Mr. Keeble is at present engaged upon a further attempt to solve this difficult problem. But the results show that in such colour-varieties of *Hippolyte* as green, brown, and pink, there is under natural conditions a production of colourless fat in the chromatophores; and that when food is withheld this chromatophoric fat is drawn upon.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor S. J. HICKSON (*Chairman*), Mr. J. E. S. MOORE (*Secretary*), Dr. E. RAY LANKESTER, Professor W. F. R. WELDON, Professor G. B. HOWES, Mr. A. SEDGWICK, *and* Professor W. C. MCINTOSH.

THE Committee report that during the session Mr. Goodrich occupied the table for a period of one month, and investigated the anatomy of the Chlorhæmidæ and the excretory organs of Enteropneusta, and that Miss Vickers occupied the table for two months and carried on some investigations on Algæ. The Committee ask for reappointment, with a grant of 100*l*.

Report on the Occupation of the Table, by E. S. GOODRICH.

I have to thank the Committee of the British Association for the use of the table at the Naples Zoological Station during one month last Christmas 1903–04.

During this short stay most of the time was spent in a search for true nephridia in Balanoglossus. The search, however, was unsuccessful, and so far no definite excretory organs have been found in the Enteropneusta.

The rest of my time was occupied in the study of the anatomy of the Chlorhæmidæ, a group of Polychæte worms which is very incompletely known. I succeeded in obtaining a considerable amount of valuable material, and hope shortly to publish some account of my researches.

FIG. 1.—A Roll Wave leaping the Outfall of the Grünnbach Conduit.

FIG. 2.—Roll Waves spontaneously formed in the Conduit of the Grünnbach.

Illustrating the Report on Terrestrial Surface Waves.

Terrestrial Surface Waves and Wave-like Surfaces.—Fourth Report of the Committee, consisting of Dr. J. SCOTT KELTIE (*Chairman*), Dr. VAUGHAN CORNISH (*Secretary*), Lieut.-Col. F. BAILEY, Mr. JOHN MILNE, *and* Mr. W. H. WHEELER. (*Drawn up by the Secretary.*)

[PLATE VII.]

THE Committee record with deep regret the death of Mr. E. A. Floyer, M.R.A.S., Mem. Inst. Egypt, a Member of this Committee, who was especially interested in the study of desert sand-dunes. A list of his principal writings upon this and other subjects, compiled by Dr. Cornish, has appeared in the 'Journal of the Royal Asiatic Society,' May 1904.[1]

In the last report some account was given of observations upon the Bore of the river Severn, and of the waves in the Whirlpool Rapids of Niagara River. Further observations upon waves in rivers and upon kindred phenomena in waterfalls were commenced in May last in Switzerland, as well as observations upon Steps and Ledges produced by the Movement of Soil upon a Slope. The work is still in progress, but a preliminary account may here be given of one kind of wave of special interest now being kept under observation in the Guntenbach and Grünnbach streams, which flow in the latter part of their course in open paved conduits into the Thunersee. Each terminates in a waterfall which is not steady, nor merely flickering, but is affected by a regular cadence having a period of several seconds. In the case of the Grünnbach the phenomenon is easily visible at the distance of a mile with the naked eye. The amount of water at maximum is fully one-third greater than at minimum. This cadence is due to the arrival of waves resembling a bore, but travelling down channel more rapidly than the current flows.

These it is proposed to call *Roll Waves*, from a name which a correspondent gives to a wave of similar form which sometimes occurs in the river Tees. It is the form, as far as can be judged by written and verbal accounts unaccompanied by photographs, in which sudden floods sometimes travel down a river, as in the recent destructive flood at Nikko, Japan. The remarkable thing about these waves in the Guntenbach and Grünnbach, however, is their periodicity, and the fact that they are spontaneously evolved without the co-operation of any special quickening, or checking, or sudden swelling of the current. They appear to depend mostly upon the shallowness of the stream (and therefore require a fairly smooth bottom), in conjunction probably with considerable swiftness. The ordinary quick throbbing of the current (to which the present writer has often referred) gives rise in these very shallow streams to 'long waves' whose amplitude is an appreciable fraction of the depth of the stream. The greater of these, therefore, move more rapidly than those of lesser amplitude, and can actually be seen to catch them up. They do not, however, pass them by, but, on the contrary, incorporate them; and thus the original small, rapid, irregular throb of the stream is changed, as the stream flows on, into a slow and nearly regular cadence. The period becomes longer and more regular in the lower reaches of the conduits, as can best be observed in the Grünnbach, of which the conduit is longer and

[1] Dr. Cornish's completed paper 'On the Dimensions of Deep-sea Waves and their Relation to Meteorological and Geographical Conditions' has appeared in the *Geographical Journal* for May 1904.

more smoothly paved, with nearly vertical sides. The whole process is a beautiful example of the evolution of large waves of regular period from small, irregular disturbances, and its observation, under the simplified condition of a straight conduit, is likely to assist in the more difficult task of observing waves in natural rivers where the phenomena are more irregular.

The photography of wave phenomena has been continued and extended in this as in former years. A selection of enlargements has been sent, by request, as part of the British Photography Exhibit, to the St. Louis Exhibition.

The Committee ask for reappointment.

On the Accuracy and Comparability of British and Foreign Statistics of International Trade.—Report of the Committee, consisting of Dr. E. Cannan (*Chairman*), Dr. B. Ginsburg (*Secretary*), Mr. A. L. Bowley, Professor S. J. Chapman, Sir R. Giffen, *and* Mr. R. H. Inglis Palgrave.

The Committee have added Mr. A. J. Sargent to their number. Mr. Palgrave has unfortunately been unable to take part in their proceedings. The Committee have made such inquiries as proved possible at the Board of Trade, and of persons actually engaged in commerce, and have examined and tabulated the information contained in the official statements of trade of various countries. The main sources of their information are given below.

The Committee decided to restrict their inquiries for the present year to the following countries: United Kingdom, United States, Germany, France, Belgium, Holland, Russia, and Austria. They also decided to consider mainly questions of value rather than of quantity. They divide their report under the following ten headings:—

A. Definition of international trade.
B. Methods of estimating value.
C. Registration of origin and destination.
D. Changes in A, B, and C in recent years.
E. The discrepancies between statistics published by different countries.
F. Relation of total of exports to the produce of a country.
G. Relation of the statistics of imports and exports to the balance of trade.
H. Accuracy of the figures of the United Kingdom.
J. Conclusion and suggestions.
K. Bibliography.

A. *Definition of International Trade.*

At first sight it seems a simple matter to define foreign or international trade. To the ordinary apprehension it would appear that a complete account of international trade would give, in the first place, particulars of the quantity and value of every kind of goods crossing international frontiers in each direction. There is little difficulty in imagining an ideal world in which it would be quite easy to collect and publish such statistics, but in the actual world things are not nearly so

simple. Even the position of the national frontier is not always what we should expect; for example, trade between France and Corsica, and between the United States and Hawaii or Porto Rico, is domestic trade; though trade between France and Algeria, and between the United States and the Philippines, is international trade. This is a simple matter compared with the complication introduced by the existence of free zones, like the free port of Hamburg in Germany, and that of Copenhagen in Denmark. Yet the position of the customs frontier is among the least of our difficulties.

We can easily imagine a world in which international trade, or goods carried across a national frontier, fell into four distinct classes, as follows:—

Imports.	Exports.
Class 1.—Goods imported which will be used or consumed at home.	Goods produced at home and exported.
Class 2.—Materials and components imported in order to be made up in the country and then exported.	Manufactured articles made up of foreign materials and exported.
Class 3.—Goods imported which will be sold for export without change of form.	Goods of foreign origin exported after purchase and sale within the country.
Class 4.—Goods simply passing into the country on their way to another country without changing ownership within it.	The same goods passing out of the country.

The first is sometimes called 'special trade,' the second 'improvement trade' (Veredelungsverkehr), the third may be called *entrepôt* trade, and the fourth 'transit and transhipment trade.' The sum of the four may be called 'general trade,' or this title may be confined to the sum of the first three.

In the real world, however, these four classes are not sharply divided by distinct and easily ascertainable lines of demarcation. It is often impossible for anyone to say for certain when an article is imported, whether it belongs to the first, second, or third class. When an article is exported the exporter has frequently no exact knowledge as to its origin, and when it is made up of various components or ingredients, part of domestic origin and part of foreign origin, it becomes impossible to classify it under the first or second head without adopting some arbitrary standard as to the degree in which a commodity must contain foreign ingredients before it can be classified as of foreign origin. Again, the distinction between the third and fourth class is a slight one, not always easy to verify. Finally, the fourth class is not very distinctly divided from goods carried in ships past the country instead of into the country and out of it. No one would propose to reckon in the transit trade all the goods in ships which have simply passed through the territorial waters of a country, nor even those in ships which have called at a port to coal; but as to what exact amount of detention and manipulation in port is required to constitute arrival and departure of goods, considerable difference of opinion may legitimately prevail.

As the benefit derived from international division of labour or localisation of industry is frequently very small, it is often the case that transactions in Class 4 are just as advantageous to a country as transactions in Class 1, but popular opinion tends to regard the 'special trade' as more important than the 'improvement trade,' the improvement trade as

more important than the *entrepôt* trade, and the *entrepôt* trade as more important than the transit trade. Consequently, most countries have been in the habit of devoting more attention to the earlier classes than to the later, and the result has been that the statistics of the later classes are not sufficiently complete to allow of useful comparison between the totals for all four classes.

The unfortunate result of this is that we cannot keep clear of questions of classification in the comparison of statistics of international trade. We have to compare totals which confessedly do not include all imports (all things carried in) and all exports (all things carried out), but only a portion of them, and the different countries do not agree as to what portion should be included.

It is becoming the practice to call the portion of foreign trade of which the more detailed statistics are kept, the 'special trade,' and the whole or any larger portion of foreign trade of which any statistics of totals (quantity or value or both), the 'general trade,' but the distinction is not always applicable, and is sometimes confusing.

In the United Kingdom the largest total for imports includes everything except gold and silver and goods for transhipment,[1] the largest total for exports ('British and Foreign and Colonial produce') includes everything except gold and silver and goods transhipped.[1] The transhipment trade and imports and exports of bullion are given separately. The grand total of exports just described is divided into totals for 'British produce' and for 'Foreign and Colonial produce,' the information as to the division being obtained from the exporters—British produce meaning, apparently, not only everything grown, but also everything manufactured in the United Kingdom, whether composed in part or wholly of foreign materials or not. The grand total of imports is divided, so far as quantities are concerned, into totals 'retained for home consumption' and re-exports. Thus, if the smaller totals be taken as 'special' and the larger as 'general' trade, it may be said that the United Kingdom special trade includes our ideal Classes 1 and 2, and the general trade Classes 1, 2, and 3.

The United States arrangement is the same in theory, but instead of the home consumption being ascertained by deducting quantities re-exported as declared by the exporters from the total imported, it is taken simply as the quantity and value 'entered for consumption' at the customs warehouse or barrier. The Committee are inquiring as to the exact treatment of re-exports.

France includes in the 'general trade' everything coming in or going out, except gold and silver, so that her grand totals include all four of our ideal classes. In 'special trade' she includes only Class 1, and such part of Class 2 as has paid duty; but sugar is treated exceptionally, all imports and exports being included.

The German 'special trade' totals include Classes 1 and 2, and such part of 3 and 4 as are not liable to duty and have not been declared for re-export; 'general trade' totals include in addition foreign goods re-exported after they have been in the customs warehouse. Trade with the small districts (in Hamburg, &c.) which are free of duties is regarded as foreign trade. Duty-free material for shipbuilding is not included in any of the returns, nor goods sent abroad to undergo a manufacturing process

[1] A small quantity of these goods passes from port to port under customs control.

and be returned. Many changes have been made in these definitions (see Section D below).

Belgium follows France as a general trade; her special trade includes Classes 1, 2, and 3.

Holland also follows France as to general trade, but compiles no returns of value for it. As to special trade, the Dutch returns include Classes 1, 2, 3, and, it is said, much of 4.

Russia includes Classes 1, 2, and 3 in special trade.

Austria includes Classes 1 and 3. Neither Russia nor Austria compiles totals of general trade.

Attention may be specially called to the general absence of adequate distinction between home and foreign produce in exports. In the case of duty-free goods, the foreign produce is in general included in special exports, a category generally supposed to include home produce only; if dutiable goods have paid duty and are then re-exported, they are also included as home produce. Thus France includes 44,000,000 francs' worth of cotton in her special exports. The lines of division are determined rather by fiscal circumstances than by economic principles.

Table showing roughly what classes of goods (see above, p. 303) are included in the Return of Special Trade of various countries.

United Kingdom	Imports: Classes 1, 2, and 3. Exports: Classes 1 and 2.
U.S.A.	Classes 1, 2, and 3 (if duty free).
France	Class 1, and Classes 2, 3, and 4 if duty has been paid, or if they are not distinguished by importers from Class 1, and all sugar in Class 2.
Germany	Classes 1, 2, and most of those parts of Classes 3 and 4 which are duty free.
Belgium	Classes 1, 2, 3.
Holland	Classes 1, 2, 3, and a large part of 4 not adequately distinguished.
Russia	Classes 1, 2, and 3.
Austria	Classes 1 and 3.

B. *Methods of Estimating Value.*

The typical method of valuing imports and exports is as follows.

A permanent commission estimates the prices of all the main articles of trade year by year, and values all exports and imports by the price-list thus established. The list at the end of one year is used for the monthly returns of the following, but the annual returns are adjusted for the change of prices in the year in question averaged through the year. The goods are valued as at the moment of crossing the frontier.

The main exception is the United States, which values imports at their price at the port of shipment in the country of origin. Thus, Bradford goods exported to the United States are entered in their accounts at their value at Liverpool.

France and Belgium began to estimate values on the typical method in 1847, Austria in 1877, Germany in 1879. In Germany an allowance is made for tare, the value entered being that of the goods without their packings. In Belgium some goods are entered by the shippers by their values alone, no quantity, tale, or measurement being given; in these cases the values declared by the importer or exporter are accepted after scrutiny.

Holland enters values as declared by shippers for dutiable goods, but the official values on which the rest of her trade statistics are based come from a fixed list many years out of date,[1] and her trade statistics have not the connotation as those of other nations for this reason.

In Russia the values of goods are declared and compared with trade price-lists under expert advice.

The United Kingdom takes declared values, but in many cases the figures are adjusted as described below.

The adjustment of values to values at crossing the land frontier must be arbitrary, and there may be uncertainty at what point goods coming by sea are valued. It is quite uncertain how goods not on the official list, or not capable of brief description, would be valued in Germany, France, &c. ; presumably some form of declared value must be used.[2]

In the United States imports are entered at the value ready for shipment declared to the American Consul at the place of exportation. The values entered are those given on the invoices before inspection or appraisement for customs purposes. Exports of home produce, &c., are entered at the market value at the time and place of shipment, re-exports at their import value.

It should be noticed that official values of exports have no necessarily close connection with the values actually realised abroad and remitted for separate consignments. They assume too great a uniformity in value. Also, there must be great error in pricing goods according to their description in all those cases where the goods are not seen and examined. Thus, the values affixed according to the official list to goods which do not pay duty, seem in most cases to be liable to considerable error.

C. *Registration of Origin and Destination.*

The classification of imports and exports according to origin is in a state of hopeless confusion. It is sometimes held that goods should be credited to the country where they are paid for ; thus, eggs from Austria sent to England on an order made to Austria should be credited to Austria, and not to Germany, Holland, or Belgium, through which they pass, while Swiss wines ordered of a Paris wine merchant should be credited to Paris. The place for payment is in very many branches of trade not the country of origin, and this plan, if carried out, would show the balance of trade but not its channels. The country of origin is not easily definable. A cargo of rails ordered by an English merchant to be shipped at Antwerp and delivered in Yokohama, may be duly credited either to Belgium or England, according to definition ; but if raw cotton is shipped from U.S.A.

[1] The list in use is still in the main that framed in 1868, which was based on a still older list.

[2] The following semi-official communication throws interesting light on this point: 'In general there is no special difficulty in fitting unusual imports into one or other of the headings specially provided in the accounts. When, in course of time, the article becomes important, a new heading is reserved for it. Thus motor-cycles were formerly grouped as "other cycles" in the French accounts, and turbines as "machines and parts thereof of wrought iron or other common metal" in the German accounts. These articles now have separate values allotted to them.

As regards pictures, the French accounts provide that *objets de collection* shall be valued at their declared value, and pictures are apparently classed under this head. On the other hand, in the German accounts, all pictures are entered by weight and valued accordingly, viz. at 20 marks per kilogram in 1901 and 25 marks per kilogram in 1902 and 1903.'

to England, spun in Lancashire, woven in Germany, and exported through Austria to Turkey, which is the country of origin? It is quite impossible to draw the line, even in theory, between simple transhipment and complete manufacture, and we are driven by necessity and convenience to tabulate goods according to the place at which they are paid for, thus increasing out of reason the trade statistics of *entrepôt* countries.

Most of the countries dealt with make an effort to enter goods according to the place from which they are shipped on a through bill of lading, or to which they go by a direct (rail and steamship) trade route. Thus, Swiss goods exported through Germany to Liverpool would be given in the Swiss statistics as exported to England, though their ultimate destination might be the United States. Imports are credited, so far as known, to the country from which they started on a through journey, but very frequently, when transported by sea, simply to the port at which they were shipped. The papers available for customs inspection very frequently do not show whence the goods came or where they were ordered, but only the place from which they made a through journey; and the actual purchaser may very likely not know the real source.

In some countries no attempt is made to get over these difficulties, and goods are credited simply to the country whose frontier they first cross or over which they came, whether by sea or land; no country succeeds in getting any homogeneous or exact returns by any other method. In the United States the statistics profess to relate simply to the country whence the goods are imported or to which they are exported, and it is not clear whether the country of origin or ultimate destination is meant or not.

France has endeavoured to get the real destination or origin since 1870.[1] The result is that goods by rail are credited to the place of consignment, goods by road or canal to the adjacent country, and goods by sea to the port of shipment or of lading, unless it is known that at these ports the goods were only transhipped; except in the case of known through lines of trade, when the goods are credited to their destination or origin as far as is known. Much trade between U.S.A. and France is probably counted in her returns as with England.

In Germany an attempt is made to get the real destination or origin. This is considered to be the place to or from which the goods travel in unbroken transit, or with immediate transhipment.

In Belgium an attempt is made to get the real origin and ultimate destination, but with very imperfect results, the overland trade being frequently credited to the wrong country.

In Holland no attempt is made in the case of goods leaving or entering the country by land, to get the real origin or destination; but goods, whether by rail, road, river, or canal, are simply credited to the adjoining country. Goods by sea are credited to the port for which the vessel cleared, or from which she last cleared.

In Austria, since 1890, the intention has been to credit goods to the country of origin or destination, but how far this intention has been carried out is not known.

In Russia goods are credited to the country whose frontier they first pass or over which they arrive.

In the United Kingdom the place from which imported goods have been shipped and the real destination of exports are aimed at, with results discussed below.

[1] See *Tableau Décennal du Commerce de la France*, 1887–1896, p. xvii.

D. *Changes in A, B, and C in recent years.*

United Kingdom.—Value of ships and boats (new), with their machinery, has been included among the value of exports of home produce in 1899 and subsequent years. Changes were made in systems of valuation and tabulation in 1854 and 1870.

United States.—Since 1898 the statistics given in the British Statistical Abstract for Foreign Countries are sometimes for the year ending June 30 and sometimes for the calendar year.[1] Great care must be exercised to know which is quoted in particular lists. Porto Rico and Hawaii have been regarded as part of U.S.A. in trade statistics since July 1, 1900. The Philippines are still treated as foreign.

From 1866 to 1883 the values of imports included their whole cost up to their arrival in U.S.A., together with a commission of at least $2\frac{1}{2}$ per cent. From July 1, 1883, the values were taken as those at the place of manufacture before being packed; since August 1, 1890, the value has been taken of the goods packed and delivered at the port ready for shipment, but no sea freight is included.

France.—There have been no changes of importance since 1847, except that the registration of goods, according to origin and destination, has been improving since 1870. Before 1895, provisions taken on board ships for use in the voyage were regarded as exports to the countries for which the ships were bound; they are now entered separately as 'Provisions de bord.'

Austria.—In 1885 goods were credited to the adjacent country, over whose frontier they passed; in 1895 the real origin and destination were entered. The date of the change appears to have been 1890, when the trade returns were reformed.

Belgium.—The value of rough diamonds imported, and cut diamonds exported, has been included only since 1897. Revised instructions as to registration of origin and destination were issued in 1882 and 1897, but these made no change in principle.

The Committee know of no changes in the methods of dealing with trade statistics of *Holland* or *Russia.*

Germany.—Changes have been so frequent and so complicated, that it is a matter of the greatest difficulty to compare year with year. In 1879 the whole system of the trade statistics was transformed, and comparisons between years before and after that date are practically impossible.[2]

Before 1884 'a large class of imports and exports were specifically excluded, namely, all articles imported free of duty for working up and for exportation in a more finished condition (improvement trade).'[3] For some time after 1884 separate totals were given for 'special trade,' including and excluding improvement trade, while the 'general trade' totals included it. Since 1897 only the inclusive total has been published. Great care must therefore be exercised before using these totals in deciding how this trade is treated.[4]

[1] Compare the 28th and 29th numbers.

[2] See 'Waarenverkehr des Deutschen Zollgebiets mit dem Auslande im Jahre 1880,' I. Theil, and the translation in C. 8211, p. 70.

[3] Quoted from C. 5597, which contains a translation of the regulations for collecting and tabulating German statistics (with definitions of special trade, &c.), which have been for the most part in force from 1880 till the present date.

[4] See Cd. 1199, p. 10 note, and No. 131 of 1904, p. 3 and p. 8 note, for the corrections necessary since 1897.

From 1897 the values of ships exported or imported have been included in special and general trades.

Changes of tariff have frequently affected the inclusion of commodities under one or other of the totals, as can be seen by examining the definitions given in A above ; there seems no possibility of estimating their effect.

Considerable changes took effect in 1889, when parts of Hamburg, Bremen, and other less important districts, hitherto treated as foreign, were included in the Zollgebiet. At the same time transit trade was excluded from general imports and exports.

General.—Comparisons year with year in the statistics of most of the countries discussed are liable to be vitiated (1) by changes in fiscal laws by which goods are transferred from the free to the dutiable list, and therefore (see remarks under A) from general to special trade in the enumerations ; (2) by the continual alteration in trade routes, by which goods may appear in the statistics of, say, France instead of Germany, without any change in their origin or destination, and for reasons already explained affect the 'special' as well as the 'general' trades of these countries ;[1] (3) by the varying success with which goods are credited to their countries of origin and of destination.

While it is very unfortunate that such confusion exists, it is clear that few of the difficulties so far discussed are due to inaccuracy in the actual returns. In most countries the statistics are compiled primarily in that way which is most useful for their fiscal purposes, and secondarily in such a way as to give information to their own people. No two countries are in quite similar commericial situations, or have identical fiscal policies, and the non-comparability of statistics naturally results. The most perfectly accurate statistics readily lead to inaccurate deductions, when their origin, nature, and limitations are not thoroughly understood.

NOTE TO SECTION D.

The following statistics indicate the relative importance to be attached to the changes described :—

United Kingdom.
1 = £1,000,000.

—	1899	1900	1901	1902	1903
Value of Ships Exported . .	9·2	8·6	9·1	5·9	4·3
Value of Total Exports, home produce (including above) . .	264·5	291·2	280·0	283·4	290·9

United States.
1 = $1,000,000.

—	1899	1900	—	1899	1900
Value of Exports to			Value of Imports from		
Porto Rico . .	2·6	4·3	Porto Rico . .	3·2	3·1
Hawaii . .	9·0	13·1	Hawaii . .	17·8	20·7
Value of Total Exports (including above) . . .	1203·9	1370·8	Value of Total Imports (including above) . . .	697·1	849·9

[1] For examples of this sort see the *Report on Tariff Wars* (Cd. 1938).

Belgium.

1 = 1,000,000 francs.

—	1897	1898	1899	1900	1901
Value of Exports of Cut Diamonds	58	67	67	43	44
Value of Total Exports (including above)	1,626	1,787	1,949	1,923	1,828
Value of Imports of Rough Diamonds	55	60	60	40	42
Value of Total Imports (including above)	1,873	2,045	2,260	2,216	2,221

Germany.

1 = 1,000,000 marks.

Year	Imports : Special Trade			Exports : Special Trade		
	From Hanse Towns	For Improvement	Residue	To Hanse Towns	After Improvement	Residue
1881	572	—	2,391	630	—	2,347
1882	552	—	2,577	685	—	2,505
1883	556	—	2,708	725	—	2,547
1884	557	62	2,704	770	82	2,434
1885	502	57	2,442	693	78	2,167
1886	493	57	2,395	756	79	2,229
1887	537	61	2,588	826	89	2,309
1888	518	59	2,773	791	91	2,415
1899	50	96	3,965	105	135	3,062
1890	17	96	4,145	105	132	3,223

Year	Imports: Excluding improvement trade and ships	Imports: Including improvement trade and ships	Exports: Excluding improvement trade and ships	Exports: Including improvement trade and ships
1895	4,121	—	3,318	—
1896	4,307	—	3,525	—
1897	4,524	4,681	3,500	3,635
1898	4,958	5,081	3,619	3,757
1899	5,345	5,483	4,069	4,207
1900	5,637	5,766	4,448	4,611
1901	5,309	5,421	4,309	4,431
1902	5,514	5,631	4,559	4,678

E. *The Discrepancies between Statistics published by Different Countries.*

Many attempts have been made to reconcile the statistics of different countries, but invariably without success. For examples see the official publications, 'Trade between the United Kingdom and France,' 1881, 'Trade of the United Kingdom with Germany,' 1904, and 'Reports on Tariff Wars between certain European States,' 1904 ; see also Sir Robert Giffen's paper on the 'Use of Import and Export Statistics,' 1882, and Mr. Ellinger's papers in the 'Economic Review,' 1902, and at the Manchester Statistical Society, 1904 (see Section J below).

In no case that the Committee know of do the values registered by country X of goods imported from country Y correspond at all closely with the values registered by Y as exported to X.

As just explained, it is not in general necessary to assume inaccuracy

in the returns to account for this, for the differences in methods of tabulation necessarily cause very great discrepancies. Take the case of England and Belgium. We valued our exports of home produce exported to Belgium at 11,000,000*l.* sterling, and of foreign produce at 4,000,000*l.* in 1900. Belgium valued what she received at 300,000,000 francs, say 12,000,000*l.*, in her special trade. Of the goods we send to Belgium, a great part would no doubt pass on to other countries, and in spite of regulations much of this would be entered as going to Belgium only. Indeed, the English exporter might not know its destination beyond an agent at Antwerp. On the other hand, the Belgian importer would credit part of the 4,000,000*l.* which we described as foreign produce to the United Kingdom, and only part to the real country of origin. Such illustrations might be multiplied indefinitely. The reader is referred to the papers just named for analyses of special cases.

In addition to questions of destination, the method of valuation causes differences, especially where official values linger behind market values.

Again, goods leaving X for Y may not be delivered in Y in the same year, or they may remain in the customs warehouse of Y for many months; exact correspondence year by year is therefore not to be expected. It follows that we do not know the value of our export trade, even if we assume the statements to be made correctly, to any of those countries where transit trade is of importance, and even when we group them together, there is much uncertainty;[1] nor can we use the statistics of foreign countries to check our own. Similar remarks apply to imports. Further, we cannot estimate the total international trade of the world, or of the main groups of countries, for neither the general trade nor the special trade is defined in the same way in different countries, and the totals cannot therefore correctly be added.

In the previous paragraphs it is assumed that the returns of quantities and values are correctly made. Below, we show reason to think that this is not invariably the case in the United Kingdom. We have no means of investigating the accuracy of the statistics of foreign countries in general; but the process of valuation seems very faulty where official values are employed, and declared values are subject to bias, especially as they are found for the most part in the case of dutiable goods. The following comparison of the returns of trade between Europe and the United States shows how far we can obtain agreement in a case where, if the returns were accurate as to value and destination, there should apparently be close correspondence. This instance is taken because the basis of valuation is very nearly the same in the exporting and importing countries, for freight is not included in either.

We put all Europe, so far as figures are available, together in order, to avoid confusion of origin. The visible sources of error are the inclusion of Italian exports to Canada, which cannot be separated, and possibly of some Asiatic produce going from Russian Asiatic ports; some goods registered in Europe as going to the United States may be there treated as in transit for Canada or elsewhere; while some European trade to Canada may find its way into the United States; and in the table is included $666,000,000 (for the ten years) value of foreign goods re-exported by us, counted in our trade, and in many cases in continental

[1] On this point see the warnings prefixed to the Board of Trade *Accounts of Foreign Trade*, and alluded to in Cd. 1761, pp. vi, 3, and 4.

trade also. It will be observed that neither the amounts nor the dates of change correspond at all closely; that, in fact, we should not know from inspection of the figures that they related nominally to the same phenomena; and that we can only obtain an agreement even within 5 per cent. when we take the totals for ten years, giving the various errors the best chance of neutralising one another.

Import Trade of U.S.A. from certain European Countries[1] (i) *as Registered by the Exporting Countries, and* (ii) *as estimated in U.S.A. Statistics.*

1 = $1,000,000.

Year	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	10 years
(i)	448	387	394	355	307	426	355	386	329	395	—	3,782
(ii)	448	447	390	456	293	381	416	427	303	399	447	
Adjusted	447	409	434	348	352	404	424	344	367	431	—	3,960

The U.S.A. accounts are made up to June 30 each year. The third line in above table is obtained thus: For 1893, $\frac{1}{3}$ of $456 + \frac{2}{3}$ of $293 = 348$, assuming that about two months elapse between the valuing of the goods in Europe and their entry in the U.S.A. records.

The trade between the United Kingdom and U.S.A. is shown in the following table:—

1 = $1,000,000.

Year	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	10 years
U.K. Accounts.											
Exports from U.K.—											
Foreign produce	68	65	72	56	57	79	54	71	65	79	666
Home produce	154	132	127	115	90	133	98	101	71	88	1,109
U.S.A. Accounts.											
Imports received of produce of U.K. adjusted for dates	192	169	174	133	142	167	169	129	130	149	1,554

F. *Relation of Total of Exports to the Produce of a Country.*

The relation of the total special exports of a country to the value of the produce of home capital and labour contained in those exports is very complex. There is no evident *à priori* connection between the two; the value of exports may go up because imported raw material or partly manufactured goods have risen in value, while the home contribution has gone down or *vice versâ*. In the comparatively rare cases of commodities, where the whole value is due to home labour or capital, the connection is closer; but even here we should often have to pay regard to the cost of imports used in the implements of manufacture, such as imported machines, coal, &c.

There are in general no official published data which make it possible to

[1] Austria, Greece, Italy, Spain, Portugal, Switzerland, France, United Kingdom, Belgium, Holland, Germany, Norway, Sweden, and Russia (European and Asiatic ports). In exports from Italy are included those to Canada. Exports of foreign produce of the United Kingdom are included as exports from England.

subtract the values of imported goods contained in exports, and it would be necessary to obtain separate estimates from those conversant with each important trade before we could deal with exports as relating to the produce of home industry (on this point see Memorandum 23 in Cd. 1761). We know of no similar estimate for other countries. The Belgian, German, and French treatment of their 'improvement trade' add greatly to the difficulties in those countries. While it is illogical to use the *total* values of exports to measure the real progress of production or manufacture for export before we have an estimate such as described, it is permissible to use the values of *particular* commodities for such a purpose, in some cases where we have sufficient means of allowing for the possible causes of error. In all cases we are much more likely to come to correct conclusions when we are making a comparison of *rates of change*, whether for two countries or for one country in two periods, than when we are making comparisons of absolute amount.

G. *Relation of the Statistics of Imports and Exports to the Balance of Trade.*

The Committee do not propose to deal in detail with the causes of the difference between the total values of imports and exports, as they have been the subject of so much recent and, in some cases, well-informed discussion; but they wish to emphasise the importance of the definitions of trade and the methods of valuing it discussed in Sections A and B. The totals to be taken are those of General Trade when it includes the whole of Classes 1, 2, and 3 with or without 4; Class 4 enters equally on the two sides of the account, and it is immaterial whether it is included or not.

The method of valuation is very important. The value may be taken as any one of those in the following example:—

	£
Value of goods manufactured in inland town in country X	$1{,}000 = x_1$
,, ,, packed and ready for delivery in country X	$1{,}005 = x_2$
,, ,, at exporting agent's warehouse at port in X	$1{,}010 = x_3$
,, ,, on board at port in X	$1{,}012 = x_4$
,, ,, insured for sea transit at port in X	$1{,}017 = x_5$
,, ,, on board at port in country Y	$1{,}050 = x_6$
,, ,, delivered to customer in country Y	$1{,}055 = x_7$

[Assuming that duty, if any, has been subtracted from the last total.]

Of the sum paid by the customer in Y, 1,012*l.* will be received by various persons in X, and 5*l.* $(x_7 - x_6)$ is divided among various persons in Y. As regards the country X, the total services up to 1,012*l.* at least must be paid by money or its equivalent from abroad; as regards the country Y, not more than 1,050*l.* is to be paid by exporting money or its equivalent. The intermediate 38*l.* $(x_6 - x_4)$ may be due to X or Y or other countries. In most trade accounts the value x_4 would be taken for exports and x_6 for imports. In U.S.A. x_3 is taken for imports; in Germany x_6 is taken for imports, but an allowance is made for part of $x_2 - x_1$.

There is a risk that part of $x_7 - x_6$ may be included in imports (if market values are taken), while part of $x_6 - x_1$ may be omitted; part of $x_4 - x_1$ may be omitted from, or part of $x_7 - x_4$ included in, exports if manufacturers' invoices are the basis.

In balancing imports and exports, every part of $x_7—x_1$ must be accounted for—that is, it must be known how each part is dealt with. How far the trade accounts of the United Kingdom allow this is discussed in the next section.

H. *The Accuracy of the Figures of the United Kingdom.*

Having described the meaning of the statistics published by the various countries and their relations to two of the problems (sections F and G) for which they are often used, the next question to be considered is how far the figures published really represent the facts. We have no means of knowing the correctness of the figures published by foreign countries, and will confine ourselves to considering the possible insufficiencies or inaccuracies in those published by our Board of Trade.

Quantities and Description.

Imports.—Dutiable goods are weighed and measured with the utmost exactness. Free goods are in general weighed or measured at the docks, and the invoice return is generally checked by the customs-house official, who obtains the exact return from the importing agent after the goods are examined. Corrected returns of this sort are sent to the Statistical Department in large numbers.

Exports.—These are not checked except (by way of test) in a percentage of cases. There is no doubt great possibility of carelessness on the part of exporters; where an invoice is incorrect for any reason, it is not likely they will go to the trouble of making another and different statement for the sake of statistical accuracy, if they can avoid it. It does not follow, however, that in general reliance may not be placed upon the returns where the exporters have no motive to deceive. Stories which we have no reason to doubt, have reached us as to intentional misstatement in regard to particular articles of trade, but we have no means of verifying them and estimating what weight should be attached to this source of error.

Description of goods.—The Board of Trade classification allows the possibility of a great change in quality without any corresponding change in the category under which goods are described. Thus, cotton cloth is only registered by length, and a thousand million yards are given under one heading; but cloth is not of uniform width, fineness, weight, or finish, and, in particular, cloth is often split after manufacture into half-widths. This process would double the quantitative return without any appreciable increase in the labour spent on the goods.

In the case of woollen cloth, there is a more complete subdivision into heavy and light, broad and narrow, but goods may undergo great improvement in quality, weight, fineness, and finish without crossing the arbitrary line dividing narrow from broad, &c., and therefore without showing any difference in the returns. A careful examination of the statistics of the woollen exports shows that there has probably been a very considerable increase in quality without any increase shown in the returns.[1] Similar difficulties probably occur in very many other trades.

[1] See 'An Inquiry in the Woollen and Worsted Trades,' by C. Ogden and P. T. Macaulay, Bradford (1903).

The bills of entry, published daily with accounts of the ships entered and cleared, and their cargoes, are based on the same information as that used by the Statistical Department in their published returns; these bills are much used and valued by the merchants concerned, who are in a position to know the facts, and this would not be the case if they were not found to be substantially accurate. The bills give the values of those goods only whose quantities or numbers are not returned to the customs; they therefore supply no check on prices declared.

Values.

The declared values of imports and exports are constantly tested at the Statistical Department by market price-lists. It is found that in general values of particular commodities as declared are confined within a small range, and agree with the lists. Directly any unusual price is shown on the declaration, inquiry is made as to its cause. In general, then, the goods are entered at their correct value, and changes of price have instantly their effect on the trade returns. For this reason our statistics should show greater fluctuations month by month than those of the continental countries. There are even some cases where two invoices of exports are made, one *pro formâ* for the foreign customs, and one of the true value for our own Statistical Department.

While this method tends to give correct returns for the main lines of important and easily described commodities, it is clear that when goods are out of the common run, or are not capable of succinct description, the Department is at the mercy of the declarer. Whether values are official or declared, uncommon goods are likely to be valued wrongly.

Exports.—In the case of exports, there is a tendency to give a c.i.f. price instead of f.o.b. It is supposed that the export trade done on a c.i.f. basis is increasing in magnitude. The inland manufacturer makes out his invoice on this basis. The exporting agent has no other information, and the f.o.b. price is never known. On the other hand, when goods are sent on consignment for sale, the price entered, whether by the agent or by the Statistical Department, is likely to be the market price, and not to include the price of placing the goods on board. Lastly, the manufacturer may enter his values at the inland market price, or at the value on the docks before lading, and this may not be corrected in all cases by the exporting agent.

Imports.—Goods on consignment for sale, which form a very considerable proportion of our imports, are valued in the returns at their market price. This includes the cost of landing and delivery. All imported wool is priced in this way, the basis being the prices realised at six weekly sales, and this price is used for the six weeks after the sale, and so lags behind its true rate. Again, goods may be invoiced so as to include in their price delivery at an inland town. Lastly, it is said that the value of goods sent from a foreign firm to an agent in England in some cases are artificially increased, so as to show no profit and escape income-tax.

In the case of exports, there being no check except comparison with price-lists, entries can be filled up with any degree of carelessness so long as they do not show any abnormal deviation in price. In the case of imports, miscellaneous goods, or goods imported in small quantities, or those whose value is uncertain till they are sold, are valued almost by guess-work.

It would appear that the Statistical Department is mainly dependent on the values stated in manufacturers' invoices, that in general no second invoice is made for statistical purposes, and that such a change in custom as of offering goods to foreign customers on a c.i f. instead of f o.b. basis would increase the apparent value of exports without any real change.

A very large trade in precious stones, to a great extent transit to Amsterdam, is said to be carried on, and entered very imperfectly in imports and exports. The Cape Government state the value of diamonds exported from them to England, *e.g.*, as 5,380,300*l.* in 1902. The English import total only includes 46,841*l.* in that year. If any substantial quantity of precious stones is, as is supposed, imported into and kept in England, they are not included in our trade returns, and affect the balance of trade.

The Committee have not enough evidence to know whether, on the whole, exports or imports are under-valued or over-valued in relation to their values as defined by the Board of Trade.

Destination and Origin.

As regards *exports*, on the form which has to be filled in, the final destination, or rather the place to which the goods are consigned, has been asked for many years ; but in Parliamentary Return 131 of 1904 it is admitted that this space has not always been accurately filled up. An appeal is made in that paper to chambers of commerce and merchants to pay more attention to this statement.

It is to be noted that Switzerland and Bolivia, having no seaboard, have as yet no separate place in our trade returns.

As regards *imports* there are admittedly very many errors, and it has been practically impossible hitherto to know the origin of those goods which come from countries doing a large transit trade. In the current year 1904, an extra question has been asked on the import form and on the re-export form, asking for the country whence the goods were consigned as distinct from the country from which the goods were shipped on a through bill. It is intended to publish a supplementary table in the annual statement of trade, containing any information which this new heading brings to light, without as yet altering the existing tabulation.

The Committee welcome this as a step in advance.

J. *Conclusion and Suggestions.*

The Committee are much impressed by the extreme difficulty of handling statistics of International Trade, even when dealing with the reports of the United Kingdom whose genesis and meaning are well known to them. They recommend extreme caution in using any such statistics, for even when regard is paid to all the definitions, limitations, and sources of error analysed above, it is not at all easy to know within what limits of error the statistics may be trusted. It is possible, however, to discriminate, and to state that some of the difficulties are comparatively unimportant. The treatment of improvement trade is a small matter. The differences in method of estimating values in the United Kingdom, France, Germany, Russia, and Austria should not have much effect when a period of more than a year is in question, while the methods of Holland and U.S.A. make comparison of their statistics with those of other countries very

difficult. The inaccuracies in price statements in the United Kingdom are probably of not much importance in the main lines of goods, and the aggregate value is not much affected. It is probably safe to compare the records of total imports and total exports in particular countries with their own previous records, if we pay the necessary attention to the changes discussed in Section D above. In Germany we cannot go back beyond 1880. There is a widespread distrust of the trade statistics of U.S.A. We can compare the rates of increase in one country with those of another more safely than we can compare the actual amounts in particular years. On the other hand, we cannot at all easily compare either the total special or the total general trades of one country with those of another. We cannot divide a country's exports into those of home produce and of foreign produce in any systematic way. We cannot, however we group countries together or analyse the figures, use the statistics representing the total trade between two countries or two groups of countries, except in the roughest way, for purposes which would not be affected by a great percentage error.

The Committee make the following suggestions, which should rather be regarded as statements of the kind of information they have specially felt the want of, and which does not seem impossible to obtain, than as final expressions of opinion as to the best way of remedying the defects in our knowledge. They, however, attach considerable importance to No. 6.

1. That the Board of Trade should make an inquiry, to whatever extent and in whatever way proves practicable, as to the prevalence of erroneous statements, especially of value of exports.

2. That the Board of Trade should make an estimate of the extent to which export trade is done on a c.i.f. basis, and as to whether any source of error is introduced in the published values by this development.

3. That in the same way an estimate should be made as to the overvaluation of imports when they are valued at market prices.

4. That the classification of goods by quantity and quality at present in use is not perfect, and that the Board of Trade should consult the chambers of commerce and others as to the methods of improving it.

5. That it should be considered whether exports of textile goods cannot be entered in some way which will give more detailed information, and make the returns more easily comparable with those of foreign countries.

6. It is very advisable for the sake of the public who use the official publications that a reasoned statement relating to the accuracy and exact meaning of the returns should be inserted in every Annual Statement of Trade, and in a more contracted form in the Statistical Abstract for the United Kingdom and in the Monthly Returns. In the same way a careful and brief criticism of the meaning and accuracy of the statistics of trade of foreign countries should be inserted in the Statistical Abstract for the Principal and other Foreign Countries. As it is, it is a matter of the very greatest difficulty for even the educated public to attach the right meaning to the official returns.

The Committee regard with satisfaction the steps the Board of Trade have taken in Cd. 1761 and No. 131 of 1904 to inform the public on these matters, and trust that publications of this nature will continue to be issued.

If the Committee are reappointed they will be able to develop and extend the analysis they have already made, but they wish to represent that the inquiry is far too involved and difficult for them to carry to a complete issue, and that it should properly be taken up by the Government department concerned.

K. *Bibliography.*

The Committee append a list of the papers consulted in their investigations. They have found their labours considerably lightened by the reports drawn up by Sir Alfred Bateman for the International Institute of Statistics, in the volumes named below.

'The Official Trade and Navigation Statistics,' Bourne, 'Stat. Soc. Journ.' 1872.

Bulletin de l'Institut International de Statistique, vol. ii. p. 294; vol. xi. pp. 138 and 59; vol. xii. pp. 121 and 71.

'The Use of Import and Export Statistics,' Giffen, 'Stat. Soc. Journ.' 1882, and Essays in Finance (2nd series).

'Thirty Years' Export Trade, B. Ellinger,' 'Econ. Review,' 1902.

'Value and Comparability of English and German Foreign Trade Statistics,' B. Ellinger, Manchester Stat. Soc. (Read March 1904.)

Statistical Abstracts for the United Kingdom. (Annual.)

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Trade and Navigation Returns of the United Kingdom. (Monthly and Annual.)

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Tableau général du Commerce et de la Navigation de la France. (Annual.)

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Holland—Statistiek van den In-, Uit-, en Doorvoer over het Jaar 1902 (and similarly for previous years).

The Foreign Commerce and Navigation of U.S.A. (Annual.)

The Statesman's Year-book.

Parliamentary Papers, &c.

Trade between the United Kingdom and France: No. 405 of 1881.

Statistics of the Foreign Trade of Germany: C. 5597 of 1888.

British Trade and Production 1854–1895: C. 8211 of 1896 (p. 70).

Comparative Statistics of Population . . . in the United Kingdom and some leading Foreign Countries: C. 8322 of 1897, and Cd. 1199 of 1902.

British and Foreign Trade and Industry: Cd. 1761 of 1903.

Tariff Wars between certain European States: Cd. 1938 of 1904.

Trade of the United Kingdom with Germany: No. 131 of 1904.

The Tidal Régime of the Mersey.—Report of the Committee, consisting of Lord KELVIN (*Chairman*), Mr. J. N. SHOOLBRED (*Secretary*), *and* Professors GEORGE H. DARWIN, OSBORNE REYNOLDS, HELE-SHAW, *and* W. C. UNWIN, *appointed to obtain information respecting the Tidal Régime of the River Mersey, with the object of submitting the data so obtained to Harmonic Analysis.*

SINCE the Mersey Docks and Harbour Board have for the last sixty years been entrusted by Parliament with the charting, lighting, and buoying of the River Mersey, and have also under their charge the various gauges

along the tidal portion of that river, the Committee considered that they would be in possession of the most accurate and authentic records respecting the tidal action which has been, and is at present, taking place in the Mersey. The Committee therefore instructed the Secretary to communicate with the Mersey Docks and Harbour Board to ascertain what information they would be prepared to afford to the Committee.

It may not be out of place here to refer to the causes which have led to the appointment of this Committee. During the past thirty years several communications, and reports of Committees, connected with tides in the River Mersey have been presented to the Association. In 1885 Professor George Darwin communicated to the Royal Society a paper, summarising the results of the Harmonic Analysis of the Tides at various points—amongst others Liverpool—between 1857 and 1870.

It is well known that of recent years, commencing in 1890, great improvements, by dredging, have been gradually carried out in the entrance to the Mersey and in the approach-channels to Liverpool. In this way about eighty million tons of sand have been removed, and about 16 feet of additional depth over the bar, at the seaward entrance, have been secured for the navigation. The gradual extension of the dock and other river walls of late years have also provided for the tidal flow, a smoother and more regular channel in the Mersey.

It was therefore thought possible that the form of the tidal wave might have been somewhat affected by these causes, and that it might be advisable, in the interests of science, to verify again by means of the most recent tidal records the results previously arrived at, by the Harmonic Analysis of the Liverpool tides of some forty years ago. Hence the appointment of the present Committee.

The Mersey Docks and Harbour Board, when approached by the Secretary of this Committee, intimated through their General Manager, Mr. Miles K. Burton, that it would afford them much pleasure to assist the Committee in any way they could; and they directed their Marine Surveyor, Commander Henry Belam, R.N., to afford the Committee access to any documents which might be deemed desirable, in order to further the objects of the Committee.

After some further correspondence it was decided that 'The Register of Tides at the George's Pier, Liverpool, for the year 1902' would be best suited for Harmonic Analysis; and these records were accordingly handed by the Marine Surveyor to the Secretary for that purpose.

Mr. Edward Roberts, of the 'Nautical Almanac' Office, well known in connection with Tidal Harmonic Analysis, who had carried out the calculations of the previous investigations into the Liverpool tides of 1857 to 1860 and 1866 to 1870, was good enough to offer the Committee to investigate the tidal registers of 1902, free of expense to them, so far as was necessary to ascertain whether there was any material difference between the results for the later period, and those of the two earlier ones.

This offer of Mr. Edward Roberts having been accepted by the Committee, with thanks, the 'Register of Tides at the George's Pier, Liverpool, for 1902,' above referred to, was handed to him. Although it was only towards the end of May that it was found possible to do so, yet

Mr. Roberts has been good enough to send to the Committee, for the purpose of their present report, the following communication :—

The Harmonic Analysis of the Tides at George's Pier, Liverpool, for 1902.

The following is the Analysis of S. and M. Series of Liverpool, 1902 :—

A (Mean Tidal Range) = 4·952 feet above O.D.S.

S_2	H—3·188 feet κ—11° 32′	M_2	H—10·091 feet κ—326° 45′
S_4	H—0·043 feet κ—307° 4′	M_3	H—0·111 feet κ—319° 0′
		M_4	H—0·657 feet κ—244° 2′
		M_6	H—0·180 feet κ—353° 6′
		M_8	H—0·052 feet κ—248° 6′

N.B.—The 'κ's are referred to Greenwich Meridian, as before.

These figures are subject to revision, but can be taken correct for present comparison. I have found a few misreadings of the Tide Gauge Diagrams; it is possible that there may be a few more, but I have not time now to go thoroughly again through all the figures.

It will be seen that the above are almost the exact means of the previous two sets of three and four years, previously analysed; so that it may be assumed that the tides at George's Pier have undergone scarcely any change during the last forty years.

Eltham, August 4, 1904.

Comparison of Tidal Diagrams of Different Periods.

The Marine Surveyor, in addition to the Register of the Liverpool Tides for 1902 dealt with by Harmonic Analysis by Mr. Edward Roberts, was good enough to place at the disposal of the Committee a number of tidal curves, taken by the various self-registering gauges established by the Mersey Docks and Harbour Board, at different points throughout the tidal portion of the river, from the Bar to Warrington. A part of these tidal curves, limited in number, owing to shortness of time, were selected by the Secretary for comparison.

The several periods for comparison being 1903 as representing the present dredged state of the Bar, and the improved conditions of the tidal flow in the river ; 1893 as presenting the conditions immediately before those improvements were commenced ; and 1874 as representing a still earlier period. When, as it happened, tidal observations had been carried out under the personal superintendence of the Secretary on certain tides, at points in the higher reaches of the river where self-registering gauges have since been established. These results, together with the records of the two then existing Mersey Docks and Harbour Board gauges, at Hilbre Island, and at George's Pier, afforded a complete series of points identical with those of the later dates of 1893 and of 1903.

The tides selected for comparison were the equinoctial springs and neaps, of the vernal equinox, in the years just indicated, and the records were those of the gauges at Hilbre (the Bar), George's Pier, Eastham (Manchester Ship Canal entrance), Garston, Stanlaw Point, Widnes, Fidlers Ferry, and Warrington. These gauges embrace the entire tidal establishment of the River Mersey.

The tidal curves, at each particular gauge, showed that no material change had occurred, during the thirty years so compared, either in the range of the tide or in the form of the curve. However, in the extreme upper reaches of the narrow fluvial portion, the tidal stream set in earlier

in the flow, and remained somewhat later during the ebb, in 1903 than in 1893 and 1894. This is probably due to the increased facility afforded for the ingress of the flood tide by the deepening of the bar.

That this advance in the time of ingress of the current did not show itself in the lower and deeper reaches of the river might be explained by the fact, that the quantity of water entering is small compared with the much larger quantity already there. But in the fluvial portions of the river, above referred to, the amount of water brought by the tidal current must be considerable, compared with the land water in those parts of the river.

In any case the result of this comparison of tidal curves representing an interval of thirty years, and extending over the whole tidal portion of the Mersey, confirms what the Harmonic Analysis indicates for the tides of Liverpool itself.

The Committee desire to be allowed to present the thanks of the Association to the Mersey Docks and Harbour Board, and to their officials the General Manager and the Marine Surveyor, for their courtesy in having placed so much information at the disposal of the Committee in order to assist them in carrying out the objects for which they were appointed. Likewise the Committee wish to record their best thanks to Mr. Edward Roberts for having, at considerable inconvenience to himself, afforded them the information above referred to as to the Harmonic Analysis of the Liverpool tides of 1902.

In conclusion, the Committee desire to put on record its gratitude to Mr. Shoolbred for his care in preparing the preceding Report; and, generally, for all the time and thought which he has devoted to the investigation of the subject submitted to it by the British Association.

Archæological and Ethnological Researches in Crete.—Report of the Committee, consisting of Sir JOHN EVANS (*Chairman*), Mr. J. L. MYRES (*Secretary*), Mr. R. C. BOSANQUET, Dr. A. J. EVANS, Mr. D. G. HOGARTH, Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee report that of the grant assigned to them at the Southport meeting of the Association the sum allocated to archæological research at Knossos has been paid over, as usual, to the Cretan Exploration Fund, and expended in furthering the excavations of Dr. Arthur J. Evans, whose report on the season of 1904 is appended.

The sum, which was allocated to ethnological research, was put at the disposal of Mr. W. L. H. Duckworth for the investigation of the physical characters of the ancient and modern population of Crete on the same conditions as last year. Mr. Duckworth, however, was not able to arrange to revisit Crete, as he had proposed, in the season of 1904, but the Committee have every hope that he may be able to resume his observations there at an early date. A further grant is asked in aid of this branch of the Committee's work.

The work at Knossos also continues to promise results of the highest scientific importance, and the Committee therefore ask to be reappointed, with a further grant.

APPENDIX.

Excavations at Knossos, Crete, 1904. *By* Dr. ARTHUR J. EVANS.

The campaign of 1904 at Knossos had a threefold objective :—(1) the continued exploration of the lower strata of the palace itself ; (2) the further investigation of dependencies lying beyond what may be called the inner enceinte ; and (3) the search for the tombs.

(1) The researches within the palace area have been very extensive. Methodical explorations of the strata below the later floor levels have thrown much light on the earlier history of the site. A variety of new data have been acquired for distinguishing the first and second periods of the later palace, and fresh light has been thrown on constructions belonging to an earlier palace. The evidence of an earlier front to the west of the Central Court has become clear. New stone repositories have come to light and the original doorways of the West Magazines. In the north-west quarter further deep-walled pits have been opened out. A very important section has been cut below the pavement of the West Court revealing a succession of Middle or Early Minôan floor-levels, together with their characteristic ceramic relics. Below this, again, some seven metres of Neolithic layers were explored.

In some cists of the West Magazine were found fragments of wall paintings that had adorned an upper hall on this side. Portions of a pillar shrine were represented on these, showing fetish double axes stuck into the columns. Other fragments referred to scenes of the bull-ring and crowds of spectators. A great analogy is thus presented to the 'miniature' frescoes found in 1900.

In the north-east part of the site some of the great *pithoi* belonging to a magazine of the earlier palace have been built up. These are larger than any vessels of the kind yet discovered, attaining a height of over two metres. The magazines have been roofed over for their preservation.

(2) A Minôan roadway paved with fine slabs has been traced running westwards from the Theatral Area for a distance of over 200 metres. The work here has been very severe, as the pavement lay at a depth of nearly twenty feet below the surface, and involved the clearing away of a mass of later structures of no account. Pits sunk to the north of this line, moreover, revealed the existence of important Minôan buildings, and in order to make a preliminary exploration of these a wide cutting had to be carried out in this direction. The traces of important structures have been thus brought to light, which derive extraordinary interest from their associations. A rich deposit of inscribed clay tablets was here found referring to the royal chariots and weapons. Near one of these, mentioning a store of 8,640 arrows, were found the remains of two officially sealed chests containing a large number of carbonised arrows with small bronze heads. It is possible, therefore, that the structures form part of the royal arsenal. At this point, owing to the difficulty and expense of the work, and the advance of the season, the excavation had to be broken up. It is most necessary, however, that this promising area, extending along the newly discovered roadway, should be fully explored. Owing to the vast mass of earth to be removed a Décauville railway will be probably necessary.

(3) On a hill about a mile north of the palace a considerable cemetery

was discovered. One hundred tombs were here opened, the contents of which showed that the bulk of them belonged to the period immediately succeeding the fall of the palace. The civilisation was, however, still high, and the character of the art displayed by the relics found showed the unbroken tradition of the Later Palace Style. Among the objects brought to light were a number of bronze vessels, implements, and arms, including swords, some of them nearly a metre in length. One of the shorter swords has a gold-plated handle engraved with a masterly design of lions hunting wild goats. The jewellery and gems discovered were of the typical 'mature Mycenæan' class, and a scarab found in one of the graves is of a Late Eighteenth Dynasty type. Among the painted ware 'stirrup vases' were specially abundant, some with magnificent decorative designs. The tombs were of three main classes: (*a*) *Chamber tombs* cut in the soft rock and approached in each case by a *dromos*; in many cases these contained clay coffins, in which the dead had been deposited in cists, their knees drawn towards the chin. (*b*) *Shaft graves*, each with a lesser cavity below, containing the extended skeleton, and with a roofing of stone slabs. (*c*) Pits giving access to a walled cavity in the side below; these also contained extended skeletons. Unfortunately, owing to the character of the soil, the bones were much decayed, and only in a few cases has it been possible to secure specimens for examination. A certain number of skulls are to be sent to England.

On a high level called Sopata, about two miles north again of this cemetery and forming a continuation of the same range, a still more important sepulchral monument was discovered. This consisted of a square chamber, about 8 by 6 metres in dimensions, constructed of limestone blocks, and with the side walls arching in 'Cyclopean' fashion towards a high gable, though unfortunately the upper part had been quarried away. The back wall was provided with a central cell opposite the blocked entrance. This entrance, arched on the same horizontal principle, communicated with a lofty entrance hall of similar construction, in the side walls of which, facing each other, were two cells that had been used for sepulchral purposes. A second blocked archway led from this hall to the imposing rock-cut *dromos*. In the floor of the main chamber was a pit grave covered with slabs. Its contents had been rifled for metal objects in antiquity, but a gold hairpin, parts of two silver vases, and a large bronze mirror remained to attest the former wealth of such. A large number of other relics were found scattered about, including repeated clay impressions of what may have been a royal seal. Specially remarkable among the stone vessels is a porphyry bowl of Minôan workmanship but recalling in material and execution that of the Early Egyptian dynasties. Many imported Egyptian *alabastra* were also found, showing the survival of Middle Empire forms beside others of Early Eighteenth Dynasty type. Beads of lapis lazuli were also found, and pendants of the same material, showing a close imitation of Egyptian models. Four large painted 'amphoras' illustrate the fine 'architectonic' style of the later Palace of Knossos, in connection with which the great sepulchral monument must itself be brought. The form of this mausoleum, with its square chamber, is unique, and contrasts with that of the tholos tombs of mainland Greece. The position in which it lies commands the whole South Ægean to Melos and Santorin, and Central Crete from Dicta to Ida. It was tempting to recognise in it the traditional tomb of Idomeneus; but though further researches in its immediate

vicinity led to the discovery of a rock-cut chamber-tomb containing contemporary relics, it was hardly considerable enough to be taken for that of Merionês, which tradition placed beside the other.

The Lake Village at Glastonbury.—Sixth Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor W. BOYD DAWKINS (*Secretary*), Sir JOHN EVANS, Dr. ARTHUR J. EVANS, Mr. HENRY BALFOUR, Mr. C. H. READ, *and* Mr. A. BULLEID. (*Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY.)

AFTER an interval of five years the excavations at the Lake Village, near Glastonbury, were reopened in the spring of this year. Digging began on May 17 and was continued until June 10, under the joint superintendence of Mr. Arthur Bulleid and Mr. H. St. George Gray. The site, discovered in March 1892, was systematically explored annually for seven years, when more than one quarter remained unexamined. With the exception of the partial excavation of two dwelling-mounds (Nos. 55 and 74), undertaken by Mr. Gray during the meeting of the Somersetshire Archæological Society at Glastonbury in 1902,[1] no digging has been done.

It has recently been decided by the Local Committee at Glastonbury to excavate the remaining part of the village, and it is intended to continue the exploration for one month in each year until the work is finished. Although the number of dwelling-mounds left for future examination is comparatively small,[2] it will be seen from the accompanying plan of the village that the area of ground to be dug is large, and under favourable circumstances will take at least two seasons more to excavate.

It is proposed to publish an illustrated paper on this and every subsequent year's work in the 'Proceedings of the Somersetshire Archæological Society.' As soon as the examination of the site is complete, arrangements will be made to publish, as speedily as possible, a full and detailed account of the whole excavations, and a 'Publication Committee' of the Glastonbury Antiquarian Society has been formed to consider the most suitable way of carrying this out. The account to be published will probably take the form of a quarto volume, fully illustrated with plans and sections, and with drawings and photographs of the objects discovered. Although the greater part of the work will be dealt with by the explorers, it is proposed to invite specialists to write chapters on sections relating to subjects in which they are eminent.

The ground excavated this year is situated at the north-east part of the village. Work began with the examination of Mounds 57 and 58, partially explored in 1896. Digging was afterwards continued southwards and included the examination of Mounds 54, 55, 78, and portions of 64 and 79, left from a previous year. The area of ground between these mounds was also carefully excavated, and the remaining piece of the palisading discovered to the east of Mound 54 completes the uncovering of the boundary of the village.

Rain prevented work during two whole days; consequently, the area

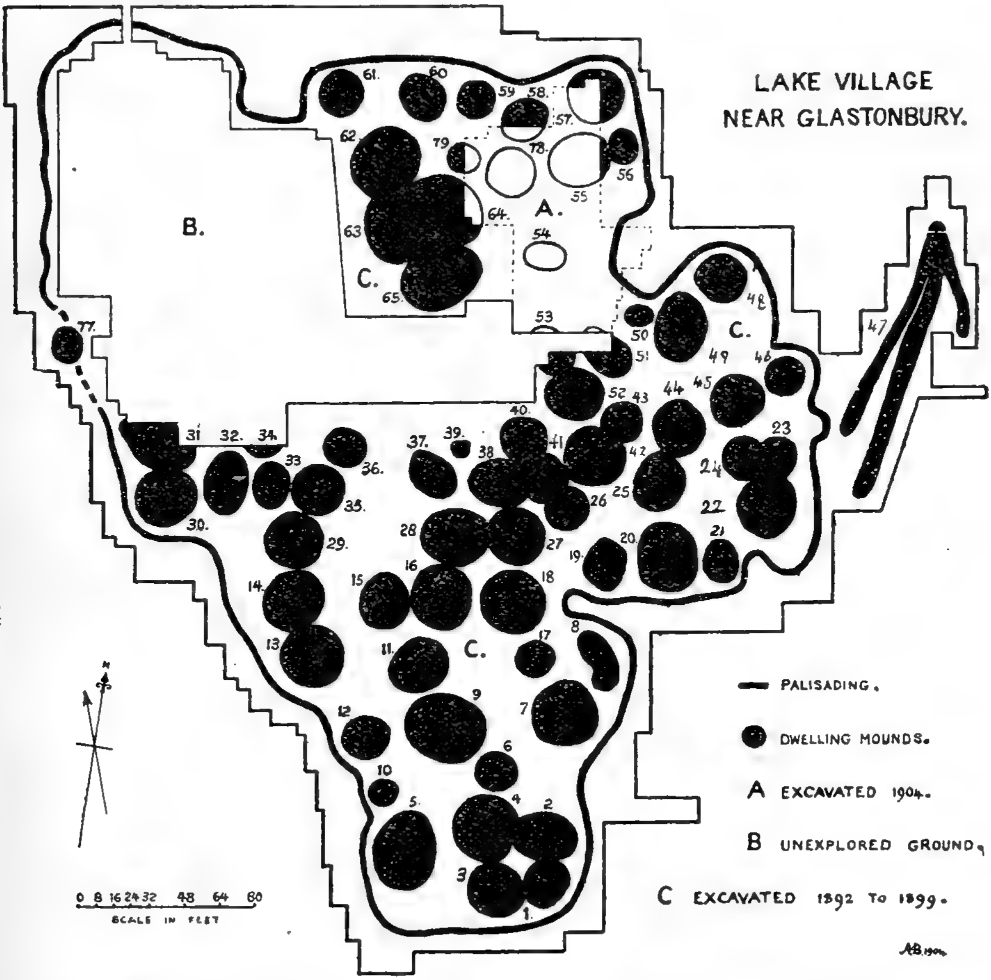
[1] Described and figured by Mr. Gray in the *Proc. Som. Arch. and Nat. Hist. Soc* vol. xlviii. pt. 2.

[2] Twelve complete, and portions of several other, dwelling-mounds.

of ground dug was not quite so large as was anticipated. It having been ascertained that the magnetic deviation for Glastonbury on January 1, 1904, was 17° 1′ west of true north, a north point was drawn on the large plan bearing the date 1904. Levels were taken in various parts of the field this year, by means of which it was ascertained that the eastern side of the village is 16 inches higher than the western side.

Sectional plans were made of the more important dwellings by Mr. Bulleid, and some excellent photographs were taken of the hearths and other interesting portions of the excavations by Mr. Gray.

Mound 57.—This mound, situated near the north-east margin of the



village, was 28 feet in diameter, with an elevation of 16 inches at the centre above the surrounding level ground. It was composed of four floors, the total thickness of the clay being 3 feet $7\frac{1}{2}$ inches. The substructure supporting the floors consisted of layers of clay and brushwood and a heterogeneous mass of timber, stones, peat, and lumps of blue clay, together measuring from 3 feet to 4 feet deep. Hearths were found on the third and fourth floors during the season of 1896. There were signs of fire and charcoal on the two upper floors, but no distinct hearth could be discovered.

Among the chief objects found in this dwelling were F 364, H 284.

Mound 58.—Situated close to the N.N.E. border of the village, and to the west of Mound 57. This dwelling-mound, 27 feet across from east to west, was composed of two floors, the total thickness of the clay being 15 inches. Well-preserved hearths were found on both floors, the upper made of clay, the lower of gravel. The latter was photographed from the N.E. and from the S.S.W. The substructure was not well arranged, except under the east side of the mound, where the pieces of timber were placed parallel, in a north and south direction.

The most important objects were B 374, E 191, F 362, F 363, H 285, K 27, P 163, S 31, S 32, S 33.

Mound 79.—This mound was composed of three floors, the total thickness of the clay being 21 inches. The surface of the lower floor was partially covered by small water-worn stones. No distinct hearth was noticed on either floor, although each layer bore evidence of fire. The substructure consisted of a layer of brushwood, kept in place by numerous small piles and some larger pieces of timber placed side by side east and west.

The only finds of importance were H 288, I 88.

Mound 78.—This mound was 24 feet across east and west, and composed of three floors of clay, not easily distinguishable. The total thickness of clay near the centre was 2 feet. Pieces of flooring-boards were noticed on the surface of the second floor; these were lying lengthways in a south-westerly and north-easterly direction. The hearth, photographed from the south, belonging to the upper floor was a circular platform of clay 4 feet in diameter, in a good state of preservation. At an average distance of 18 inches from the south-west, south-east, and north-east points of the margin of the hearth there were three slabs of lias resting on the surface of the clay floor, placed at right angles and equidistant, so as to form two sides of a square. If a fourth slab ever existed at the north-west angle it was not discovered. Nothing particularly noteworthy was noticed in the substructure.

The chief finds from Mound 78 were B 375, D 71, E 192, E 193, E 196, F 365, F 366, F 367, H 287, H 290, H 291, H 293, S 34, S 35, S 36, S 37.

Mound 55.—This mound, with a diameter 36 feet east and west, was composed of two floors, the area of the upper being considerably the greater. The hearth belonging to the upper floor was of baked clay, not well defined. Placed at varying distances from it were seven large blocks of water-worn sandstone, arranged roughly in a semicircle. The eastern margin of the same floor was covered with small rubble stone and overlapped by the clay floors of Mound 56. The second floor was of small extent, but noteworthy for the hearth, photographed from the east and from the north-east, which was quite complete and in an excellent state of preservation. It had previously been uncovered in 1902. The hearth was made of baked clay, covered with a layer of mortar-like substance. It was of circular outline with bevelled sides, average diameter at base 5 feet, at top $3\frac{3}{4}$ feet, height about 9 inches. A plan and section of this hearth is given in Plate I. accompanying Mr. H. St. G. Gray's paper, 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2. The substructure supporting the clay was well marked at the north and north-east edges of the mound. Several incomplete lines of wattle-work were uncovered among the brushwood underlying the east and south-east sides of the dwelling.

The most interesting finds were B 372 (1902), B 373 (1902), D 70

(1902), E 190 (1902), E 194, E 195, F 361 (1902), F 368, G 22, H 286, H 289, K 28, L 36 (1902), M 35, P 162 (1902), P 164, P 165, Q 39, T 11.

Mound 54.—A small mound, composed of two floors having a diameter (east and west) of 16 feet. The hearths were of baked clay, but of no particular interest. The area of flat ground surrounding the dwelling-mound was unusually large and partially occupied by patches of rubble-stone; these were chiefly situated near the south, south-east, and north-west sides of the mound. The ground to the north of the mound was firm, and few piles were met with during the examination of the peat. A number of tree stumps placed horizontally were found embedded in the superficial layers of peat and black earth, some of the logs distinctly showing the cut of an adze. The ground south of the mound was much softer, and an average number of piles was observed. The palisading lying to the east of Mound 54 chiefly consisted of a single line of posts.

The numbered objects found on or near Mound 54 were A 4, B 377, B 378, E 197, Q 40, S 38, S 39.

Mounds 51 *and* 53.—The northern margins of these mounds were cut into, and the remaining portions await completion next season.

The objects found near these mounds were B 379, F 369, F 370, H 294, H 295, Q 41, W 166, W 167.

Mound 64.—A small portion of the eastern margin of this mound was examined and completed; it yielded little of interest beyond the following objects, B 376, H 292, N 7.

List of Objects Found.

Amber. (A.)

4.[1] Small bead, max. ext. diam. 7·5 mm., length 4·3 mm.; with flattened ends and bevelled edges. Mound 54, 1904. Previously an amber bead was found in 1892, and another and fragment of a third in 1893.

Glass. (G.)

22. Bead of white glass, with sinuous grooves running round the sides, the grooves being filled up with light-yellow fused glass; ext. diam. 11·2 mm., length 10 mm. Mound 55, 1904. This is the first piece of yellow glass found in the village.

Tin. (L.)

36. Lump of tin, weight $1\frac{1}{3}$ oz. avoirdupois. Mound 55, 1902.

Bronze. (E).

190. Object which may have served the purpose of a buckle, as it certainly suggests a junction between strap-ends. Mound 55, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 3.)

191. Spiral finger-ring, composed of flat wire 2·3 mm. in width. Several similar ones have been found in the village. Mound 58, 1904.

192. Massive buckle, or ornament for strap-end, of D-shaped design, probably connected with horse-harness. The lobe-shaped knobs are typical of the Late Celtic period. It weighs $1\frac{3}{4}$ oz. avoirdupois. Mound 78, 1904. There is a similar buckle, but larger, from Knowle Hill, Bawdrip, Somerset, in Taunton Castle Museum.

193. Small ring with overlapping ends, possibly a link of a chain; ext. measurement, 10 by 11·5 mm. Mound 78, 1904.

194. Tubular piece of bronze in four fragments, taking the form of a curve (about one-third of a complete circle). Made from rolled sheet-bronze. Mound 55, 1904.

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[1] These figures represent the numbers of the 'finds,' from the commencement of the excavations, under the various headings.

195. Small ring, ext. diam. 15·5 mm.—too small for a finger-ring. Mound 55, 1904.

196. Small nail, length 12·6 mm., with flat circular head. Mound 78, 1904.

197. Rivet, diam. 10 mm., height 6·5 mm.; of a common type at the village, and of the character of those with which the bronze bowl is studded. Mound 54, 1904.

Iron. (J.)

88. Adze, in two pieces; with socket still filled by the end of the wooden shafts much corroded. Mound 78, 1904. Two or three similar implements have previously been found in the village.

Kimmeridge Shale. (K.)

27. Portion of the rim of a turned vase or bowl, which was $9\frac{1}{4}$ in. in diameter at the mouth. The vessel had a beaded lip externally, the lip being bevelled off inwards and ornamented on the top by two parallel grooves. The parallel striations caused by the lathe are well seen. Mound 58, 1904.

28. Fragment of a large ring or armlet. Mound 55, 1904.

Human Bone. (M.)

35. Fragment of parietal bone, found in Mound 55, 1904.

Animal Bone.[1] (N.)

7. Several beaver teeth. Mound 64, 1904.

Tusk. (T.)

11. Boar's tusk, with perforation at the root end for suspension. Mound 55, 1904.

Baked Clay. (D.)

70. Ball of light reddish-brown clay, almost circular, with indentations which appear to have been caused by the impress of the thumb and fingers. Mound 55, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 9.) A somewhat similar but flatter piece of clay was found this year.

71. Ball of clay, similar to a spindle-whorl, except that the hole only extends partly through the object. Mound 78, 1904. Another found at the same place is included under the heading of 'Spindle-whorls.' Portion of another was found this year.

Three small balls and fragments of clay, two having cylindrical holes extending partly through the objects. 1904.

Only sixteen sling-bullets were found this year, and one in 1902; they were mostly of fusiform shape.

Flint. (F.)

361. Small nodule of flint with natural perforation. Mound 55, 1902.

362. Small, roughly chipped implement. Mound 58, 1904.

363. Flake. Mound 58, 1904.

365. Duckbill-shaped scraper. Mound 78, 1904.

366. Small worked scraper. Mound 78, 1904.

367. Pointed flint, with secondary chipping, exhibiting signs of prolonged use. Mound 78, 1904.

368. Worked knife, with dorsal ridge and of triangular section. Mound 55, 1904.

370. Long flake with two worked saw-like edges. Mound 51, 1904.

In addition to the above, thirty fragments of flint and worked flakes were found, including a core in Mound 55.

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[1] Several wheelbarrows-full of fragmentary animal remains were collected from the excavations this year.

Antler. (H.)

284. Cheek-piece of horse's bit, with two cylindrical perforations; similar to several others found previously in the village. Mound 57, 1904.

285. Another smaller piece, similar to 292 as regards both ends. Mound 58, 1904.

286. Roe-deer antler finely worked to a smooth point, and probably used as a modelling-tool in decorating pottery. Mound 55, 1904.

287. End of deer's tine, with one large transverse cylindrical hole; perhaps a cheek-piece of horse's bit. Mound 79, 1904.

288. Small fragment of worked antler, of circular plan and 15·5 mm. long; of unknown use. Mound 78, 1904.

289. Implement of unknown use—a roughly made peg with a large head, consisting of the complete section of the antler. Mound 55, 1904.

290. Piece of antler with squared ends and of oval cross-section; probably the handle of a heavy iron knife. Mound 78, 1904.

291. Weaving-comb, which originally had nine teeth, the two outer ones being now deficient. At the other end it has a circular perforation for suspension. The comb is decorated with incised dot-and-circle ornaments in thirty-five places, without any systematic arrangement. Mound 78, 1904.

292. Large piece of antler about 9 in. long; very smooth from prolonged use at and near the point; the broad end shows the marks of the saw. Mound 64, 1904.

293. Small fragment of roe-deer antler. Mound 78, 1904.

294. Plain weaving-comb, having ten small teeth, all more or less broken. Mound 51, 1904.

295. A slender tine of deer showing little signs of having been worked. Mound 51, 1904.

Bone Objects. (B.)

372. Dentated end of a long-handled weaving-comb, which had twelve teeth in its complete state. It is a very wide example (49 mm.). Ornamented with crossed lines and circle-and-dot pattern. Mound 55, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 7.)

373. Metatarsus of sheep or goat, with condyles cut off at one end; at the articular end, an oval hole at top and another on side close to end. It could have been used as a kind of shuttle-spool in weaving—the thread being drawn off the bone as required for the weft and passing through the hole to prevent the unravelling of the wound-on thread. Mound 55, 1902. (Figured in 'Proc. Som. Arch. Soc.,' vol. xlviii. pt. 2, pl. iii. fig. 8.)

374. Fragment of bone, showing part of a rough perforation. Mound 58, 1904.

375. Two, similar to No. 373. Mound 78, 1904. A dozen or two of these objects have been found in the village.

376. Complete needle, more or less pointed at both ends; very much polished from continual use; length, 62 mm. The width of the needle increases from both ends towards the eye, which is circular (3 mm. in diam.). Mound 64, 1904.

377 and 378. Two pieces of metacarpal or metatarsal bones of sheep or goat, each about $1\frac{3}{4}$ inches long and each having three transverse circular holes through the bone on the flat sides. Probably used in weaving; a lady who has seen them states that she has observed similar objects of bone used by weavers in the North of England, but she could not explain their precise purpose. Mound 54, 1904.

379. Perforated head of femur (? human); perhaps a spindle-whorl. Mound 53, 1904.

Stone Objects. (S.)

(Other than complete Spindle-whorls and Querns).

31, 32, 33. Small, flat, circular, polished pebbles, generally supposed to have been used in games. Mound 58, 1904.

34 and 35. Two flat, almost circular, discs of sandstone; probably spindle-whorls in process of formation. Mound 78, 1904.

36. Thin, flat, smooth piece of sandstone, with incipient hole; perhaps a spindle-whorl in process of manufacture, although the object—in its present state—is, in plan, an irregular oval. Mound 78, 1904.

37. Large and fairly thick sandstone disc, with incipient hole in centre of one face; probably intended for a spindle-whorl. Mound 78, 1904.

38 and 39. Two round discs of sandstone, both having incipient central holes, as if ultimately intended for spindle-whorls. Mound 54, 1904.

Two burnishers were also found this year, a whetstone in Mound 54, and two smooth pebbles of oval form in Mound 55.

Spindle-whorls. (W.)

165. Ball of baked clay with hole extending partly through the object. Mound 78, 1904. (See No. 71, under 'Baked Clay.')

166. Sandstone spindle-whorl. Mound 53, 1904.

167. Flat sandstone spindle-whorl. Mound 53, 1904.

A small complete clay whorl was also found this year, and half of a baked clay spindle-whorl.

Querns. (Q.)

39. Lower stone of a nearly circular quern, averaging $12\frac{1}{4}$ inches in diam. at top. Mound 55, 1904.

40. Upper stone of saddle-shaped quern, length $11\frac{1}{2}$ inches. Mound 54, 1904.

41. Fragment of upper circular quern. Mound 53, 1904.

Pottery. (P.)

163. Ornamental pot or bowl, found in about forty pieces, but now completely restored; height $4\frac{1}{2}$ inches; max. diam. $7\frac{1}{8}$ inches; diam. at lip 6 inches. The decoration consists of a horizontal band of cross-hatching about 1 inch below the lip. Mound 58, 1904.

164. Small shallow earthenware pot, height 1 inch, ex. diam. at lip $2\frac{1}{8}$ inches. Probably used for mixing colouring matter. Mound 55, 1904.

165. About one-half of a highly ornamented black pottery vessel or bowl, height $4\frac{3}{4}$ inches. Ornamented over the greater part of the surface with chevrons and bands of cross-hatching; there are no curvilinear lines in the decoration. The pottery averages 7 mm. in thickness, and the pot is similar in form to No. 163. Mound 55, 1904.

Several hundreds of fragments of pottery were found this year, as in previous years, but the proportional number of decorated fragments to those with no ornamentation was below the average this year. Nearly all the pottery was lathe-turned, but half a blackish-brown pot, found near Mound 55 (height 3 inches), was hand-made, and of such a rude character that if it had been found with relics of the Bronze Age we should probably have had no hesitation in assigning it to that period. Chevrons and zigzag patterns predominated this year, and there was a paucity of curvilinear designs. It is hoped that the pottery designs of 1904 will be figured in the 'Proceedings of the Somersetshire Archæological Society' later on. (Vol. 50.)

Peas were found in some quantities in Mound 58, red colouring matter in Mounds 54 and 58, and vivianite at the bottom of Mound 57.

Anthropometric Investigation in Great Britain and Ireland.—Report of a Committee consisting of Professor D. J. CUNNINGHAM (*Chairman*), Mr. J. GRAY (*Secretary*), Mr. N. ANNANDALE, Dr. A. C. HADDON, Dr. C. S. MYERS, Mr. J. L. MYRES, Professor A. F. DIXON, Mr. E. N. FALLAIZE, Mr. RANDALL MACIVER, Professor J. SYMINGTON, *and* Dr. WATERSTON.

SINCE the meeting at Southport in 1903 the Anthropometric Committee have been engaged in drawing up a standard list of dimensions to be measured. Considerable progress has been made with this work, but as it

is not yet complete it is not considered desirable to make a special report upon it at the present time.

The Committee recommended in their last report that steps should be taken to establish an Anthropometric Bureau with the view of organising continuous anthropometric work throughout the British Isles. This recommendation has recently acquired new interest from the appointment during the past year of an Inter-departmental Committee to inquire into the question of alleged physical deterioration of the people. This Committee, shortly after its appointment, put itself in communication with the Anthropometric Committee of this section, and the chairman and the secretary were asked to give evidence before it.

As part of this evidence, the chairman and the secretary submitted a scheme for the establishment of an Anthropometric Bureau and the carrying out of a continuous Anthropometric Survey of the United Kingdom by the State.

The following memorandum with reference to this scheme has been drawn up by the chairman (Professor Cunningham):

Scheme for the Establishment of a Central Anthropometrical Bureau.

In the report upon the alleged physical deterioration of the people which was submitted by the Royal College of Physicians to the Home Office (July 27, 1903), the following opinion is expressed: 'Could an inquiry be made into the present physical condition of the nation, it is self-evident that it would be of great value; but one dealing with a portion only of the population would be likely to lead to error.' With this view I fully concur, but I would go further and insist that for the purpose of the present inquiry it would be necessary that this examination into the physical characters of the people should be continuous and carried out on a permanent basis. It is only by such a measure that statistics could be accumulated which would enable us to note the upward or downward tendency of the national physique. Valuable as the results of the British Association Committee of 1878–1883 are, it is no disparagement of its work to say that these results are admittedly incomplete. In its final report the Committee itself alludes to this, and expresses regret that the time and funds at its disposal are not sufficient to enable it to prosecute its inquiries to the end it had in view. Indeed, all the Committee claims to have done is to have laid a substantial foundation for a further and more exhaustive study of the physical condition of the people.

That the time has come when this more extended inquiry is urgently called for is self-evident, and it is with this end in view that I would urge the importance of establishing a Central Anthropometrical Bureau supported by Government and commissioned to carry out this work.

I would venture to suggest the framework upon which such a scheme could be constructed, and shall deal with this matter under the headings of:

I. Hon. Consultative Committee.
II. The Bureau.
III. Surveyors or Measurers.

I. *Consultative Committee.*

To obtain absolute uniformity in the methods of procedure in each of the three countries, it would be advisable to appoint an Hon. Consultative

Committee. This Committee should consist of three members—one from each of the three divisions of the United Kingdom. These appointments should be honorary, but the ordinary allowances for travelling expenses should be granted.

The members of the Committee should be anthropologists of acknowledged reputation who are acquainted with the structure of the human body and the laws which regulate its development and growth. They should be likewise men of weight and influence. It might be possible to carry out the work in England and Scotland without such local representatives, but I do not think that it would be possible to do so in Ireland; and indeed I consider that in each of the three countries the inquiry could be much more advantageously prosecuted by having a Committee of this kind co-operating with the permanent officials of the Bureau.

The duties of this Committee would be:

(*a*) To determine the measurements and observations to be made.

(*b*) To determine the instruments to be employed.

(*c*) To construct in connection with the Director of the Central Bureau the form of card on which the observations are to be recorded.

(*d*) Each in his own country to advise and assist the permanent officers in any cases of difficulty that may arise.

II. *Central Bureau.*

The Central Bureau should be established in London, and should be organised as a Committee of the Privy Council

It would probably be necessary to appoint a Director and Deputy Director. One of these should be an anthropologist acquainted with the anatomy and development of the human body, and with experience in anthropometrical work; the other should be a statistician trained in the methods of Professor Karl Pearson.

A Statistical Department would also require to be organised in the Bureau. The work carried out in this office would be the following:

(*a*) To keep the standard instruments and issue all the instruments required in the inquiry.

(*b*) To issue the cards on which the observations are to be recorded to those engaged in the measuring, &c.

(*c*) To arrange surprise visits at intervals to different schools, &c., with the view of determining whether the results of the surveyors are accurate.

(*d*) To receive the cards after they have been filled up, classify them, prepare the requisite statistical tables, and publish a yearly report.

(*e*) To form in London a centre where the different classes of the people may be measured, and the centre in England where the surveyors or measurers may be instructed in the methods of making their observations, and in those anatomical details which are requisite for the acquisition of accurate results.

(*f*) To disseminate information on anthropometrical work, and create an interest in the public in regard to the importance of maintaining the national physique.

III. *Surveyors or Measurers.*

The real difficulty in devising a working scheme consists in determining how the measurements are to be carried out. If the labours of

the Bureau were to be confined to school children, the matter would be easy enough. All that would be necessary would be that one teacher in each school (or, in the case of schools where there are boys and girls, a male and a female teacher) should be instructed in the methods and made responsible to return at stated periods the cards which they have filled up.

Such a limited conception of the functions of the Bureau, however, could not be entertained. If the full measure of good is to be obtained, and if precise information is to be attained regarding the national physique and its tendencies, it will certainly be necessary to measure and test large samples of the adult people of defined districts every ten years or so. This renders it essential that a staff of surveyors or measurers should be maintained. It is needless to conceal the fact that in all probability it will not be easy to induce the people of all classes to submit to the investigation. In the work which was carried out in Ireland this was a constant source of trouble, and in many cases, even with the assistance of the parish priest, it was only possible to obtain a comparatively small number of observations. Still, were the Bureau established and the Government thereby to indicate its interest in the work, the investigation (in England and Scotland at least) would be placed upon a more favourable footing. Further, the operations in the schools would familiarise the people with the methods, while the example shown by the better-educated classes would conduce to remove prejudice on this matter.

One point would certainly require to be attended to, viz., that an equal number of male and female surveyors be appointed, so that both in schools and in the adult survey each sex might be measured by surveyors of a corresponding sex.

I am afraid to hazard an opinion upon the number of surveyors that would be required. Probably thirty would be sufficient for the three countries.

The following memorandum on the statistical aspect of the scheme for an Anthropometric Survey of the United Kingdom has been drawn up by the secretary (Mr. J. Gray).

The following table shows the statistics of population, schools, and scholars in the United Kingdom:

—	Population (1901).	No. of Schools (Primary).	No. on Register.	Scholars per 100 Population.
England	32,527,843	20,153	5,881,278	18
Scotland	4,472,103	3,145	768,598	17·2
Ireland	4,458,775	8,712	737,086	16·5
	41,458,721	32,010	7,386,962	M. 17·2

For the purposes of the Survey the United Kingdom would be divided into 400 districts, each containing on an average 100,000 persons. In thinly populated rural districts the number may be smaller, and in large towns the number may be greater.

In each of these districts 18,500 persons are in the primary schools, and 81,500 are adults or very young children. Let us say 80,000 adults are available for measurement in each district.

Let us suppose that a sample of 2,000 adults is measured in each district; the total number of adults to be measured will be $400 \times 2,000 = 800,000$.

In the case of school children we must measure a sample of 1,000-2,000 for each age interval of 12 months. The total number of school children in each district is $\frac{7,386,962}{400} = 18,467$. Dividing this number into 12 age groups each of 1 year, each group will contain 1,539. This number is only just a sufficient sample. Hence, it follows that it will be necessary to measure the whole of the children in the primary schools. There are also a number of children in addition to this in the secondary schools.

Approximately it will be necessary to measure

800,000 adults.
8,000,000 school children.

Each district should be measured once in ten years. In order to keep the staff constantly employed, the measuring of the whole population may be spread over the whole ten-year period. It will be necessary therefore to measure per annum

$$\left.\begin{array}{r}\text{80,000 adults}\\ \text{and 800,000 school children}\end{array}\right\} \textit{i.e.}\text{, 40 districts.}$$

Taking 250 working days per annum, it will be necessary to measure

320 adults per day,
and 3,200 school children per day.

If we have a staff of 20 surveyors it will be necessary that each surveyor measures

16 adults and 160 school children per day.

This, I think, allowing for unavoidable delays in getting at the persons to be measured, is a reasonable amount of work to expect from one surveyor per day, assuming that only four dimensions are measured.

It has been suggested that instead of whole-time surveyors, teachers should be employed part of their time in measuring the children in their own schools.

Permanent surveyors, being constantly employed at the same work, and frequently tested by superintendent surveyors, would measure very much more accurately and probably at less cost to the State than the teachers.

The objections which apply to teachers would apply in a less degree to factory inspectors. If these men in the course of their ordinary duties come frequently to London, Edinburgh, and Dublin, the cost of instructing them would thus be materially reduced. But owing to the fact that only part of their time could be devoted to measurement, more sets of instruments would be required, and their skill would be inferior to that of permanent surveyors.

An approximate estimate of the cost of whole-time and part-time surveyors shows clearly, I think, that the employment of a specially trained permanent staff of surveyors to carry out the whole anthropometric survey, instead of employing teachers, factory inspectors, or other existing officials, will be much more economical and much more efficient.

In the Appendix is given a record of some of the anthropometric work which has been carried out or initiated in the United Kingdom in the

past year. The record does not profess to be complete, as it contains only such work as happens to have been brought under the notice of the secretary. The Committee express a hope that persons engaged in anthropometric work will send a short account to the secretary for insertion in future reports of the Committee. Several school managers and teachers have addressed inquiries to the Committee with the view of getting instructions for carrying out anthropometric work in their schools. In some cases practical instruction has been given to these applicants, and, in others, written instructions.

The Committee again beg to acknowledge the assistance given by the Anthropological Institute in providing headquarters for the Committee, and in granting permission to hold meetings in their rooms.

The Committee desire to be reappointed with instructions to continue the work indicated in the above Report. As the grant of 5*l.* made to the Committee two years ago has now been expended, and as it will probably be considered advisable to prepare blocks of the human figure showing the points between which measurements are to be made, an expenditure over and above the ordinary expenditure for secretarial work will be necessary. The Committee, if reappointed, ask for a grant of 10*l.*

APPENDIX.

Pigmentation Survey of the School Children of Scotland.—A survey of the hair and eye colours of the school children in Scotland has been carried out during the past year by the Scottish school teachers, under the direction of a Committee consisting of Sir William Turner, Professor R. W. Reid, Mr. J. Gray, and Mr. J. F. Tocher. The schedules with instructions, and circulars containing a statement of the objects, were sent out on the 7th December, 1903, to all the 3,150 primary schools in Scotland. By the end of December 700 returns had been sent in by the teachers. Up to the present time over 2,300 returns, representing 530,000 children, or about 70 per cent. of the whole, have been received. The teachers have taken up this scheme with the greatest enthusiasm and have shown great interest in the objects and progress of the survey. The analysis of the statistics is now being proceeded with. The data obtained will be available for the determination of races and the study of the laws of heredity.

Physical Characters and Morbid Proclivities.—Dr. F. C. Shrubsall has published a paper on the results of an important investigation on the above subject in the St. Bartholomew's Hospital Reports, vol. xxxix. This deals with a study of the physical characters of hospital patients, taken chiefly from the medical wards of St. Bartholomew's, Brompton, and the North-Eastern Children's Hospitals. The observations on hair and eye colour were made on about 8,000 patients, on stature on 2,000, and on head form on 400. At the same time some observations were made on the number of generations each individual had lived in London.

The conclusions arrived at were :—

1. That the average *head form* seemed to be much the same both in hospital patients and healthy individuals, and that no differences were to be found among patients suffering from different groups of disorders.

2. That patients suffering from rheumatism and heart disease were on the average a little taller than the general population in the sphere of

attraction of the hospital, while patients suffering from pulmonary tuberculosis, nervous diseases, and cancer were shorter than the general average.

3. That the average stature both of hospital patients and their visitors decreased with each successive generation of city life.

4. That blonde traits are associated with acute rheumatism, its sequelæ and congeners.

5. That brunette traits are associated with pulmonary tuberculosis, nervous diseases, and cancer.

6. These observations were supplemented by others on small numbers only, from various parts of the British Isles, but the tendency was found to be everywhere in the same direction.

7. That medical patients in children's hospitals are fairer than healthy children from the same area.

8. That brunette traits increased with successive generations of city life among the visitors to patients in hospitals, but not among the patients themselves.

9. That the geographical distribution of disease in the British Isles and on the Continent suggests some relation between the frequency of physical types and the rate of mortality from the diseases of special selection mentioned above.

Measurements of the Insane.—During the past year a survey of the physical characters of the inmates of lunatic asylums in Scotland has been carried out by Mr. J. F. Tocher, with the assistance of two trained assistants. The survey is due to the suggestion of Dr. J. Macpherson, one of the Commissioners of Lunacy for Scotland, through whose good offices every facility was given by the authorities for making the observations. Altogether 4,436 males and 3,951 females have up to date been measured, the characters noted being the following: (1) maximum head length; (2) maximum head breadth; (3) auricular head height; (4) stature; (5) shape of nose; (6) hair and eye colours. The nature of the mental affection was also noted. The actual data, giving a complete record of individual measurements, will shortly be published,[1] and also an analysis of the statistics, and some observations on the nature of the results obtained.[2] The instruments used were Gray's sliding callipers and head height meter.

Measurements of School Children.—Five hundred school children in Aberdeenshire and 500 in Glasgow have been measured by Messrs. J. F. Tocher and R. Tocher. The same measurements were made as on the lunatics, and in addition measurements of the curvature of the cornea and the visual acuity of the children were made. The instrument used to determine the corneal curvature was a Hardy ophthalometer.

Measurements in Dorsetshire.—At the invitation of Mr. Baxter of Sherborne a number of the peasantry of North Dorsetshire have been measured by Mr. J. Gray. Length, breadth, and height of head, minimum frontal breadth, and auricular radii to the nasion and the alveolar points were measured. Mr. Baxter, who has been personally instructed in the art of making measurements, is continuing the work, and when sufficient statistical data have been accumulated a paper on the results will be offered to the Anthropological Institute.

[1] By the Henderson Trust.
[2] This paper will appear in *Biometrika*.

Gipsies.—Mr. McCormick, who applied to the Secretary of the Anthropometric Committee for instructions, has commenced along with Dr. McKie a series of measurements on the gipsies in the Border Counties of Scotland. As we already possess measurements of old Border families by the late Dr. Gregor, a comparison of these with gipsies will be interesting.

Excavations on Roman Sites in Britain.—Report of the Committee, consisting of Dr. A. J. EVANS (*Chairman*), Mr. J. L. MYRES (*Secretary*), Professor BOYD DAWKINS, Mr. E. W. BRABROOK, *and* Mr. T. ASHBY, *appointed to co-operate with Local Committees in Excavations on Roman Sites in Britain.*

THE Committee was appointed at Southport in 1903 with the object of assisting excavators of Roman sites in Britain to deal with the subsidiary problems of palæontology or non-Roman archæology which present themselves not infrequently in the course of an excavation which has primarily a Roman objective.

The Committee has accordingly made itself acquainted with the course of the excavations which have been in progress on Roman sites during the past year, and has been favoured in certain cases with summary reports of their work, an abstract of which is given in Appendices A and B.

After full discussion of the circumstances thus brought to its notice, the Committee has decided to offer grants in aid of special researches on certain sites as follows:

A. At Silchester: (*a*) to continue the careful examination of the wells found in the course of the work, with special reference to the stratification of their contents, and to the identification of the remains of plants and animals which may be found therein.

(*b*) To investigate in detail the remains of the wall and ditch, with special reference to the relation in which the irregular wall-outline stands to the rectangular street-plan within it.

B. At Caerwent: (*a*) To examine the contents of wells in the same manner as at Silchester.

(*b*) To determine the age and construction of the mound and ditch by cutting a complete section, or otherwise.

The Committee is satisfied, from the experience of its first year's working, that the method of co-operation which has been adopted has justified itself, and accordingly asks to be reappointed, with a further grant.

APPENDIX A.

Excavations at Silchester, 1903–4.

The excavations of 1903 were begun on May 15, and continued without break until October 31. Despite the exceptionally wet season a considerable amount of ground was explored, and the discoveries were decidedly above the average.

The area of the excavations was a triangular portion of the large field, covering most of the southern half of the town, immediately south-west of *insula* XXXII., explored in 1902.

The southern part of this ground contained the foundations of at least six buildings and part of another. Three of these were houses of the corridor type, but they did not present any novel features. To the north of these buildings the trenches early disclosed traces of another of very considerable dimensions, the clearance of which was not completed until late in September.

This building formed, apparently, the principal baths of the Roman town. It consisted of a block of many chambers, measuring about 145 feet from north to south and nearly 100 feet from east to west, and including all the usual parts of a Roman bathing establishment. It has undergone various alterations which make its architectural history more than usually interesting.

Attached to the northern end of the baths was a courtyard or cloister, with covered alleys, by which it was approached. Time did not permit of this being fully explored last year, but the further examination of it has been the first work of the season of 1904.

The area excavated in 1903 did not contain many pits, and owing to the saturated state of the ground it was impossible to clear out more than a few on the higher level. The number of miscellaneous finds for the year was therefore inconsiderable. The exploration of the baths yielded a number of interesting architectural fragments, including a small altar, portions of capitals and bases, part of a large basin of Purbeck marble, and other worked pieces of the same material, and some singular pieces of metal.

The search for remains of plants, &c., in the filling-in of the pits and wells, which has been pursued with such conspicuous success during the last six years, has been continued by Mr. A. H. Lyell. The results have been examined by Mr. Clement Reid, F.R.S., who has identified the seeds of several more plants not hitherto known to have been introduced into this country so early as the Roman period.

A detailed account of all the discoveries was laid before the Society of Antiquaries on June 9, and will be published in 'Archæologia.' A special exhibition of the antiquities, &c., found was held, as in former years, at Burlington House, by kind permission of the Society of Antiquaries, from June 13 to June 25 inclusive.

The excavations of 1904 have been confined to the completion of the work on the baths. The whole of the entrance court has been exposed, and is found to have been paved with stone slabs and surrounded by covered ambulatories. It has been enlarged from its original limits by lengthening it eastwards and westwards, and by adding on the north-east a large latrine. There is also interesting evidence, in the form of a sleeper-wall, with some of the bases *in situ*, of an original pillared portico; but this was abolished when the present street-lines were laid out, because it lay in the line of a street.

This street seems to have bordered, or cut through, a large pond or reservoir west of the courtyard of the baths, and its margin was protected throughout by camp-shedding or lines of piles, which may have carried a wall. No walls were encountered, but samples have been kept of the contents of the drains and latrine, which may yield curious and interesting results. Care is taken to secure samples from every pit and well, and Mr. Clement Reid has now been able to identify 130 distinct species of plants which can be proved by these excavations to have been growing in and about the Romano-British town during its existence.

APPENDIX B.

Excavations at Caerwent, 1903–4.

The excavations on the site of Caerwent (*Venta Silurum*)—a small Romano-British country-town, enclosed by a rectangle of walls of about 400 by 300 yards—have been carried on every summer since 1899, and in 1902–3 during the winter also; and reports on them are regularly presented to the Society of Antiquaries and published in 'Archæologia' (vol. lvii., Part II. onwards). A paper was also presented by Mr. T. Ashby, jun., to the British Association in 1903, 'Proc. Brit. Assoc.,' Southport, 1903, p. 806; printed more fully in 'Man,' 1904, p. 69.

Hitherto a little more than one quarter of the ancient city has been laid bare, but the greater part of the excavations has been filled in again. The local Committee hopes eventually to explore all those parts of the site which are not occupied by the houses and gardens of the modern village.

A temporary museum exists on the site; but a considerable proportion of the objects which are found will eventually be deposited in the Corporation Museum at Newport, Monmouthshire.

A well which was explored in 1903 yielded some interesting specimens of plants, which have been examined and described by Mr. A. H. Lyell, F.S.A., and Mr. Clement Reid, F.R.S. Another well has been discovered, from which it seems likely that similar plant remains may be recovered; but it has not yet been explored. The cost of opening such wells is considerable, as the men expect extra pay, and have also to be insured against accidents. There is, moreover, need for a good deal of pumping while the work is going on.

Two discoveries made in the excavations of 1904 deserve brief notice here. The first is that of the South Gate of the city: it corresponds in plan and in size almost absolutely with the North Gate, and the inner arch is in a very fair state of preservation. Like the other gate, it has been blocked up in Roman times, an aperture having been left for the egress of a drain. It was generally supposed to have stood where a modern farm road crosses the line of the south wall, some remains of the gate which were actually visible having been taken to be the traces of the attachment of a bastion tower. None of those who have written upon the topography of Caerwent seems to have suspected the truth which a few hours' digging made clear.

The other discovery is that of the base of a statue dedicated to Mars (with the epithet *Lenus[si]ve Ocelus Vellaun*), and the *Numina Augustorum* (under the names of *Lenus*, . . ., *Ocelus*, and *Vellaunus*) by M. Nonius Romanus. It bears the date A.D. 152. It had been used as building material in a cross-wall of late date.

Anthropometric Investigations among the Native Troops of the Egyptian Army.—Report of the Committee, consisting of Professor A. MACALISTER (*Chairman*), Dr. C. S. MYERS (*Secretary*), Sir JOHN EVANS, *and* Professor D. J. CUNNINGHAM. (*Drawn up by the Secretary.*)

THE Committee have to report the following progress in the elaboration of the anthropometric data which were acquired during the year 1901–2 in Egypt and the Soudan.

The cards of the 1,005 Egyptian fellahin measured have been sorted into provinces, and their measurements have been carefully copied out and collated, province by province, ready for publication. The cephalic and nasal indices have been determined, wherever possible, for each individual. The Copts have been considered separately from the Mahommedan population. Individuals whose parents belong to different provinces have been set apart in a 'mixed' group. Averages have been struck of the stature, maximal and minimal chest- and calf-measurements for the Mahommedans of each province and for the Copts.

Certain measurements, the length, breadth, and horizontal circumference of the head, the cephalic and nasal indices, have been studied in greater detail with the object of obtaining the coefficients of variability and correlation for various districts. Such data have great biological interest, seeing that the anthropometric material now available from Egypt covers a range of some seven thousand years. The variabilities of certain provinces have been compared *inter se*, and with (α) Professor Petrie's prehistoric Naḳada skeletons measured by Miss Fawcett, Dr. Warren, and others; (β) a series of Theban mummy-skeletons; (γ) a series of modern Cairo skeletons from the museums at Leipzig.

The modern population of the Ḳena province shows slightly less variability and correlation in head, length, and breadth and slightly greater variability in cephalic index than the 'prehistoric' Naḳada population of this province. It may well be, therefore, that the homogeneity of the Upper Egyptians has not been seriously disturbed during the last seven thousand years; but this conclusion cannot be regarded as certain until the variability of other measurements has been similarly studied. The greater variability of Theban mummies would be easily explicable on the ground of racial impurities in so famous and populous a city as ancient Thebes. The objection that modern conscripts are not representative of the Egyptian population, owing to the influence of stringent selection in stature and chest-measurement, may be disallowed on various grounds. There is no evidence either of correlation between stature and cephalic index or of the infiltration of a taller race into Egypt. Moreover, stature depends, as is well known, upon climate and nutrition as well as upon heredity. Lastly, the tallest Naḳada individuals show even slightly greater variability in the above measurements than does the general population.

The Coptic population appears to be decidedly more variable than the Mahommedan. This surprising result, if confirmed by investigation of further points of comparison, may be due to the greater struggle for existence for so many centuries besetting a small Christian in the midst of a Moslem population. It may be that the chance of survival is greatest for those who show the most tendency to variation, so that the Copts, in spite of their freedom from relatively modern Arab admixture, still show greater variability than the Mahommedans. They appear actually to be more variable than the 'mixed' group of Mahommedans, but to be distinctly less variable than the modern Cairene series, town populations, as might be expected, always showing the most marked heterogeneity.

Anthropological Teaching.—Report of the Committee, consisting of Professor E. B. TYLOR (*Chairman*), Mr. J. L. MYRES (*Secretary*), Professor A. MACALISTER, Dr. A. C. HADDON, Mr. C. H. READ, Mr. H. BALFOUR, Mr. F. W. RUDLER, Dr. R. MUNRO, Professor FLINDERS PETRIE, Mr. H. LING ROTH, *and* Professor D. J. CUNNINGHAM, *appointed to inquire into the present state of Anthropological Teaching in the United Kingdom and elsewhere.*

THE Committee desire to acknowledge with thanks the replies to their inquiries, which have been received from some seventy universities and colleges.

A preliminary survey of the data thus collected is made at the Cambridge Meeting informally; but the reduction of the material in the hands of the Committee to uniform and intelligible shape is a work of some difficulty, and makes it necessary to postpone the publication of the full report until next year.

The State of Solution of Proteids.—Second Report of the Committee, consisting of Professor HALLIBURTON (*Chairman*), Professor WAYMOUTH REID (*Secretary*), *and* Professor E. A. SCHÄFER, *appointed to investigate the State of Solution of Proteids.*

IN the last report evidence was given for the cases of ovalbumin, serum albumin, and globulin that the so-called solutions of these substances are really hydrosols, *i.e.*, extremely fine suspensions in water, the evidence being that carefully prepared fluids containing these substances exert no osmotic pressure upon a membrane impermeable to the proteid when water is exhibited on the opposite side.

It was also mentioned that by collecting the washings during preparation of the proteids mentioned, removing the salts, and boiling down *in vacuo* at 25°–30° C., a fluid quite free of proteid could be obtained, which gave a lasting osmotic pressure on a formalised gelatine membrane.

The experiments of the past session have been devoted to finding a non-proteid substance to which gelatine is impermeable, though in true solution, which might account for the osmotic pressure of serum against its filtrate through gelatine, a pressure ascribed by Starling and Moore to serum proteids which my past experiments indicate are not in solution at all, and therefore not liable for the pressure noted by these observers.

The material gained by washing serum proteids has been too small in amount to permit of satisfactory analyses, so that a series of substances likely to occur in sera (fresh or stale) have been employed for osmometric observation.

The following substances all gave negative results: Calcic phosphate, calcic sulphate, sodic phosphates, sodic chloride, sodic carbonate, serum ash, soap, peptone, urea, glucose, indol, tyrosine, leucine, tryptophane, choline, glycerophosphates of sodium and calcium, acid hydrolysis products of proteid (fibrin), dialysed *extractum carnis.* All these substances went through the membrane and so gave no lasting pressure.

Many of them were tried in the presence of osmotic pressure-free proteid, but again the results were negative.

Finally two nucleic acids (prepared quite free of proteid), the one from yeast, the other from thymus gland (adenylic acid of Kossel and Neumann), were found in neutral solution in sodic or ammonium hydrate to give a lasting osmotic pressure on the membrane used in the proteid experiments. It is, of course, not maintained that nucleic acid is the substance which gives rise to the osmotic pressure of serum against its filtrate through gelatine, but the result indicates that such a gelatine membrane may be quite impermeable to certain substances in true solution.

Other experiments have been conducted with a specially purified caseinogen taken up in lime water to form the so-called neutral and basic calcium caseinogenates. The former clotted with rennin and became more opalescent at 40° C., clearing again on cooling.

Neither of these preparations gave any osmotic pressure, and are therefore considered as hydrosols and not as true solutions.

Finally a series of experiments with hæmoglobin have been instituted, but are not yet completed. The spectrophotometer has been used throughout, and no product used for osmometric work unless giving the Hüfner constants in two regions of the spectrum. The onset of warmer weather and the removal of the laboratory to other premises have put an end to the further prosecution of this part of the work, but it is intended to take it up again next session.

The Physiological Effects of Peptone and its Precursors when Introduced into the Circulation.—Interim Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Professor W. H. THOMPSON (*Secretary*), Professor R. BOYCE, *and* Professor C. S. SHERRINGTON.

THE METABOLISM OF ARGININ.

IN previous experiments it had been ascertained that arginin in the form of a neutral solution of its carbonate may be injected into the circulation of a dog without producing harmful, or, indeed, any pronounced effects. It proved inert as regards blood pressure, and had no immediate influence upon urinary secretion, beyond that which could be attributed to the solvent employed.

In the following experiments arginin was administered to dogs either hypodermically or with the food, and its effects upon nitrogenous metabolism observed. When submitted to the action of barium hydrate, arginin readily undergoes hydrolytic cleavage, and yields urea and ornithin (diamido-valerianic acid).

$$\mathrm{CNH}\begin{array}{l}\diagup \mathrm{NH_2} \\ \diagdown \mathrm{NH.CH_2} \\ \quad\ (\mathrm{CH_2})_2 \\ \quad\ \mathrm{CH.NH_2} \\ \quad\ \mathrm{CO.OH}\end{array} + \mathrm{H_2O} = \mathrm{CO}\begin{array}{l}\diagup \mathrm{NH_2} \\ \diagdown \mathrm{NH_2}\end{array} + \begin{array}{l}\mathrm{CH_2.NH_2} \\ (\mathrm{CH_2})_2 \\ \mathrm{CH.NH_2} \\ \mathrm{CO.OH.}\end{array}$$

That is to say, half the nitrogen of arginin appears as urea and half as

di-amido-valerianic acid (ornithin), or, of the 192 parts by weight of arginin and water, 60 parts appear as urea and 132 parts as di-amido-valerianic acid. With these facts in view the following experiments were performed, in some of which the substance was administered hypodermically, in the others with the food. The same animals were used for both sets of experiments, the two forms of administration being carried out consecutively on each animal, an interval of some days being allowed between.

The conclusions which may be deduced from the results so far obtained are as follows :

1. Feeding with arginin as chloride or carbonate gives rise to an increased excretion of nitrogen in the urine, chiefly as urea.
2. For every 100 parts of nitrogen administered as arginin with food, 72·8 to 96·3 parts reappear in the form of urea. But, as stated, when transformed in the laboratory only half the nitrogen appears as urea, the other half as ornithin.
3. In the animal body ornithin, therefore, is either not formed, or, if so, is largely reconverted into urea.
4. Much the same effects are obtained when arginin is administered by subcutaneous injection, except that more nitrogen is excreted in the urine than could have been derived from the arginin.
5. The excess of nitrogen thus excreted cannot be attributed to the action of the solvent employed. One must therefore conclude that arginin, thus administered, stimulates nitrogenous metabolism.
6. The 'urea-nitrogen quotient' (relation of urea-nitrogen to total nitrogen) is increased during arginin administration, thus bearing out the conclusion that a large percentage of the arginin nitrogen is converted into urea.
7. No arginin nitrogen is excreted with the fæces.
8. In one experiment glycosuria followed the administration of arginin.

Metabolism of the Tissues.—Report of the Committee, consisting of Professor GOTCH (*Chairman*), Mr. J. BARCROFT (*Secretary*), Sir MICHAEL FOSTER, *and* Professor STARLING.

THE work undertaken under the auspices of this Committee has concerned itself with the gaseous and nitrogenous exchange of certain glands —to wit, the salivary glands, the kidneys, and the pancreas.

The blood gases of the salivary glands had already been worked out, and within the year results have been obtained of a similar nature for the pancreas and for the kidney.

In each case it appears that functional activity is always, under normal circumstances, accompanied by a large increase in the oxygen taken from the blood.

Taking eight comparisons of the blood coming from and going to the pancreas, it appeared that the resting gland, or rather the tail of the resting pancreas, uses up ·25 c.c. of oxygen per minute, while the same portion, secreting under the stimulus of secretin, uses up ·92 c.c. of oxygen per minute. As the average rate of blood flow through the gland was the same in both cases, we seem justified in concluding that the oxygen used up was due to the activity of the organ.

Our experiments on the pancreas have been performed both by the

ferricyanide method and by the pump, *i.e.*, by methods of a wholly different nature and on a different scale, the former method requiring 1 c.c. for each analysis, the latter 10 c.c.

In the case of the kidney we have obtained results of a similar character. The amount of oxygen taken in by the kidneys when they are not secreting, or scarcely secreting, is of the order of ·5 c.c. per minute; but in the injection of a saline diuretic, or urea, the oxygen taken in rapidly rises, and we have in one case got an exchange of 15 c.c. per minute. This is an isolated case, but an intake of the order of 5 c.c. per minute does not seem to be exceptional in cases of rapid diuresis.

We performed several experiments to see whether the effects of a diuretic could be observed on the general respiration, and, on the whole, with negative results. The respiration becomes too much upset from other causes. These experiments gave us data for calculating what ratio the oxygen taken in by the kidneys, as previously determined, bore to the whole oxygen exchange of the dog. In the case of our last experiment a dog of the size we used would absorb about 60 c.c. of oxygen per minute. Its kidneys were using up 6 c.c. during diuresis—a tenth of the whole oxygen intake.

We have not only noted the volume of the urine secreted, but also the 'work' done, as indicated by the freezing-points of the urine and the serum. So far we have found that increase of oxygen and increase of work go hand in hand.

Our experiments on the nitrogenous balance-sheets have not yet got past the stage of suiting the methods available to the purposes in hand. Messrs. Laidlaw and Mottram have been working at the possibilities of Kjeldahl's method and Gottlieb's methods respectively.

The oxidation taking place in any of the three glands named, the submaxillary, the pancreas, or the kidney, is many times greater than would be indicated by their mass.

The Respiration of Plants.—Report of the Committee, consisting of Professor H. MARSHALL WARD (*Chairman*), Mr. H. WAGER (*Secretary*), Mr. F. DARWIN, *and* Professor J. B. FARMER.

THE money placed at the disposal of this Committee (15*l.* in 1901 and 12*l.* in 1903) has been expended on apparatus for researches carried out by Dr. F. F. Blackman and Miss G. L. C. Matthaei. These researches deal quantitatively with the effect of temperature and light upon CO_2-assimilation by green leaves. The relation between this process and temperature has been worked out in detail by Miss Matthaei, and the full account will be found in the 'Philosophical Transactions' of the Royal Society, Series B, vol. cxcvii. 1904, pp. 47–105.

In this work attention was paid to several important points which had been neglected by previous workers. Of these, one is that all the leaves shall have been kept before the experiment under similar conditions of illumination and temperature; and another, that the real internal temperature of the leaf under investigation shall be known. When working with intense light, which necessarily heats up the leaf considerably, it was found practicable to arrive at the leaf-temperature thermo-electrically by inserting a fine thermo-junction into the substance of the leaf.

Taking these precautions, a satisfactory series of estimations through a range of temperature from — 6° C. to + 45° C. was obtained.

The general conclusion is that there exists for each temperature a *maximal assimilation specific to that temperature.* The amount of light required to produce the specific maximal assimilation varies directly with the magnitude of the maximum. When this is once reached further increase in the illumination or in the amount of CO_2 supplied produces no longer any augmentation of the assimilation.

The amount is just determinable at — 6° C., and then rises rapidly with higher temperatures, giving a curve which is convex to the temperature abscissa. The curve is similar to the accepted curves for the effect of temperature on respiration, and it rises more and more steeply at higher temperatures—certainly up to 38° C.

At temperatures about this point the leaf is not capable of maintaining its initial high rate of assimilation for any long time, so that the values obtained for successive hourly estimations with the same leaf form a rapidly declining series. The higher the temperature the shorter the duration of the period of maximal assimilation, and it becomes experimentally impossible with hourly estimations to obtain the maximal value at temperatures close to the fatal temperature of 45° C. The final numbers actually obtained, which can be only *sub* maximal, show a conventional 'optimum' at a temperature about 38° C., with a subsequent very rapid decline.

The relation between CO_2-assimilation and various intensities of natural illumination has been worked out by Dr. Blackman and Miss Matthaei conjointly. The detailed research is in course of publication, but it may be stated here that determinations have been made of the assimilatory value of the natural illumination at dawn, at midday, in sun and shade, during rain and storm, and at dusk. It is shown that the diffuse light of the whole heaven compares favourably with feeble direct sunshine as an illuminant. Estimations have also been made of the exact fraction of sunshine which is required to produce the specific maximal amounts of assimilation for a given temperature (30° C.) both with cherry-laurel leaves and with leaves of *Helianthus tuberosus*.

From these and other determinations it seems to follow that equal areas of different leaves (though of very dissimilar types) require identical amounts of light to produce the same amounts of CO_2-assimilation.

Botanical Photographs.—Report of the Committee, consisting of Professor L. C. Miall (*Chairman*), Professor F. E. Weiss (*Secretary*), Mr. Francis Darwin, *and* Mr. A. G. Tansley, *on the Registration of Photographs of Botanical Interest.*

Fifty photographs have been added this year to the Register, which now contains 230 photographs. The additions have been contributed by the Rev. T. A. Lea, Mr. Francis J. Lewis, Professor F. W. Oliver, Mr. A. G. Tansley, and Mr. Arthur Reid. They illustrate some of the botanical features of the British coast and British moorlands, the flora of the Alps, and of the Mediterranean, and are the type of photograph of which it will be very useful to have a record.

The additional grant obtained from the Association has been expended in providing mounts and binders for storing the photographs, and also for the purchase and printing of cards to make a classified catalogue, in addition to the Register. The completion of this catalogue has occupied some considerable time on the part of the Secretary, but it was felt that the catalogue would make the collection more serviceable by facilitating reference to any particular photograph.

As some inquiries have been received regarding the photographs which have already been registered, the Committee suggest that the list of photographs now registered might be printed by the Association and circulated among members of the Association, corresponding societies, and donors of photographs. By this means the usefulness of the Register would be increased, and the owners of photographs of botanical interest would become acquainted with the scope of the Register, and would also learn what photographs might usefully be added to the list.

Experimental Studies in the Physiology of Heredity.—Report of the Committee, consisting of Professor H. MARSHALL WARD (*Chairman*), Mr. A. C. SEWARD (*Secretary*), Professor J. B. FARMER, *and* Dr. D. SHARP.

Report to the Committee by W. Bateson, M.A., F.R.S.

IN January 1904 Mr. R. C. Punnett, Fellow of Gonville and Caius College, came into partnership in these experiments, and from that date the work has been carried on jointly. The Sweet Pea work has been done jointly with Miss Saunders also. Besides poultry and sweet peas, on which we now report, preliminary trials with other subjects are in progress.

I. POULTRY.—*Colours.*—Some complex cases are under investigation, and respecting these a report is deferred.

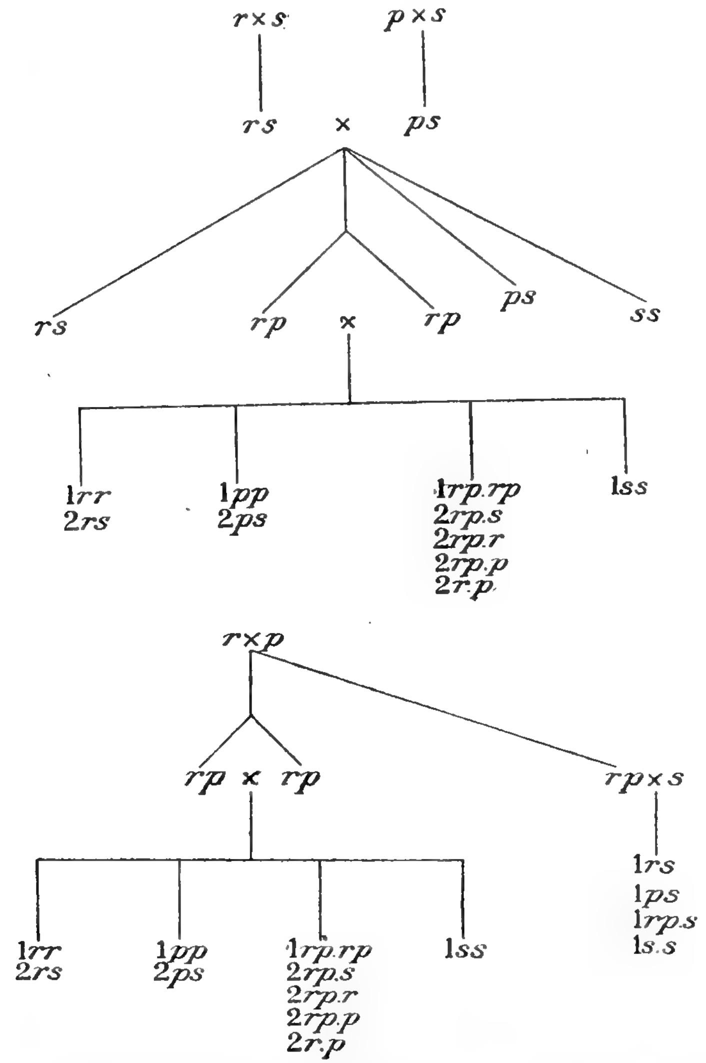
The case of the Andalusian fowl has been studied in detail. It appears that the typical blue colour is a heterozygous character, the gametes bearing black *or* a splashed white in approximately equal numbers. The extracted black is pure. The white probably can split again, giving off a purer white.

The colour, Brown-breasted, with purple face, is dominant over Black-breasted (practically *Gallus bankiva*) strongly in ♀♀, weakly in ♂♂. The segregation, judged on the down, is nearly perfect. The adult colours are not yet worked out.

Combs.—The relation of the four forms, rose (r), pea (p), rose-pea (rp)=Malay 'Walnut,' and single (s) has formed a main subject of our work; r and p are each dominant over s; $r \times p$ gives rp; rp is dominant over all. rp, whether formed directly by crossing pure $r \times$ pure p, or indirectly by crossing $rs \times ps$, gives off four types of gametes, r, p, rp, s, in approximately equal numbers. The origin of s here is uncertain. It seems to be connected with the failure of segregation in the case of the rp gametes. $rp \times rp$ therefore produces ten actual types of birds, distributed thus in appearance, $9rp$, $3r$, $3p$, $1s$. $rp \times s$ gives on an average equal numbers of all four visible types. Of the five possible types of rp birds, four have been found experimentally. It is not yet known if

rp . *s* is distinguishable from *r* . *p*. Extracted *r* and *p* of course are pure from *rp*, and from *p* and *r* respectively.

The scheme of descent is as follows :—



In view of these facts we are determining the condition of thorough-bred Malays in respect of comb. Of the five types which theory shows to be possible, four have been found in pure Malays or Malay Bantams (proved by crosses with *s*). Malay breeders often get *p* birds from pure-bred *rp*, and such *p* birds are not able to transmit *r* or *rp*. It is, however, doubtful whether *r* and *s* birds occur in pure breeding, a fact which raises a distinct problem not yet solved. We suspect the existence of a complexity dependent on sexual differentiation.

II. Sweet Peas.—*Shapes.*—'Cupids' and 'Snapdragons' Mendelize simply. Long and round pollens do the same, but in certain families there is some problematical coupling with colour.

Colour.—Numerous lines of experiment are being followed. The following case illustrates the nature of the work : E. Henderson (white).

round pollen × ditto ditto long pollen gives (usually) purple F_1. F_2 sometimes has only three colour-types—purple, red bicolor, white; but others have five—purple, purple-picotee, red bicolor, red-tinged white, white. On the purple side the great majority have *long* pollen, while of the reds most have *round.* Statistical relations not yet determined. The whites are 3 long : 1 round.

Some coloured F_2 plants give in F_3 no whites; and, though the point is not yet proved, the presumption is that some failure of segregation occurs in gametes of F_1. The other possibility is that this phenomenon is due to simultaneous homozygosis of independent allelomorphs.

A family from Lady Penzance × E. Henderson (long), showed abortion of anthers in certain F_2 individuals. The ♀ cells may be fertile. This sterility on ♂ side has Mendelian inheritance; but, probably as a fortuitous accident, the ratio approaches 4 fertile : 1 sterile (instead of 3 : 1). With rare exceptions, coloured types with *dark* axils are fertile, *light* axils going with sterility. Hence the fertile whites (though *light* axilled) must bear the character 'dark axil,' a point which can be proved next year.

The following scheme shows the probable distribution of forms:

(Pink) Lady Penzance × E. Henderson, long (White)

Purple F_1

Coloured dark axil fertile	Coloured light axil sterile	White fertile	White sterile
9	3	3	1
		1	

The Conditions of Health essential to the carrying on of the Work of Instruction in Schools.—Report of the Committee, consisting of Professor C. S. Sherrington (*Chairman*), Mr. E. White Wallis (*Secretary*), Mr. E. W. Brabrook, Dr. C. W. Kimmins, Professor L. C. Miall, *and* Miss Maitland.

The Committee had in co-operation with them in their investigations and deliberations the valuable assistance of Dr. C. Childs, Mr. Felix Clay, Dr. Clement Dukes, Miss Findlay, Miss Ravenhill, Dr. Rivers, Mr. J. Russell, Dr. C. Shelly, and Dr. Sydney Stephenson.

During the year the new Education Act has come into force, and many of the new educational authorities, in arranging their work for the coming session, are devoting considerable attention to the question of the training of teachers. The Regulations issued in July by the Board of Education for the training of teachers set out under their professional training, as the sum of the whole matter, the following weighty recommendations.

'The students ought to have an adequate knowledge of school hygiene. They should understand the general conditions necessary for making a building or a room healthy and for keeping it so, and they should be well acquainted with the rules of personal health, and, so far as possible, with the psychological principles upon which these rules are based. In the

case of women students, the nutritive value of foodstuffs in connection with their cost in the market, and in relation to the needs of young children, should be known in outline, even though the student may not be specially qualified in domestic economy. Only thus will they know how to conduct the school as a whole with the greatest profit to the health and bodily development of the scholars, and how to adapt the instruction to the limitations which are imposed in some cases by the feeble health of the children or by the poverty or neglect of their parents.'

In the prefatory memorandum to the Regulations it is stated that 'The student should, therefore, be so trained as to be capable, subsequently, as a teacher, of comparing and contrasting the phenomena of life and energy in nature as they offer themselves in the particular neighbourhood and conditions in which he and his scholars may find themselves; and this will not be achieved merely by the systematic sequence of any formal syllabus of Nature study, which may prove to have been in no way related to the conditions of what are ultimately the teacher's surroundings. His own systematic study must be within the field of natural science in its strictest sense; the more he knows of this, the better will be his equipment, provided he can bring this knowledge to bear upon the phenomena which surround man wherever he may be, and which shape or obstruct his relations with other animate or inanimate beings, and provided he uses his scientific training and knowledge as an aid in encouraging the children to observe for themselves facts, and their relations to other facts, rather than as a means for instructing them in what they should see or look for.

'It is the duty of the training colleges to see that each intending teacher shall devote some portion of his period of training to study in which the method above described shall be thoroughly, even laboriously, carried out. To apply such principles to the whole instruction of a training college is not feasible in existing circumstances, and the extent to which it is possible in any particular college must necessarily depend on the qualifications of the staff and the resources, in the form of libraries, practising schools, laboratories, &c., available for the use of the students. But it should be remembered in every case that the student who has built up for himself, on the best foundation he can find, a series of conclusions, each of which has been submitted to the most searching tests his means enable him to apply, will have acquired an insight into the true nature of knowledge which no other process of instruction can furnish. Even though that part of his mental equipment which is deeply impressed with this special character may lie within narrow limits, the student will have learnt by trial the value of rigorous inquiry, he will have gained the power to revise and correct his own knowledge when time brings wider experience and riper judgment, and he will have acquired an outlook upon the mental processes concerned in the growth of knowledge in the individual mind, which will be of lasting service to him in his professional work as a teacher.

'Every training college, therefore, should attempt, even if it be only in a limited degree, to conduct its instruction, in as many branches of the curriculum as possible, in such a way that there shall be in the case of each student some range of knowledge within which there is no fact and no inference from facts, which has not been subjected to the severest test at his command.'

No subject will offer a better field for this, the process of tested knowledge, than the subject of school hygiene, for while it offers excellent opportunities for practical work and testing methods, it co-ordinates with nearly all other branches of the teacher's work, and affords an amount of diversity and adaptability which would make its adoption practicable in nearly all colleges; and, if adopted, would give a living groundwork to educational methods which, to be successful, must be based on the conditions of health essential to carrying on the work of instruction in schools.

It is obvious that the teaching of the laws of health in schools will have little effect in training the scholar in the observance of these laws unless they are observed and practised in the conduct of the school, and such training can only be accomplished where the teachers have themselves been trained by practical and experimental work to understand (1) How the laws of health enter into every department of school life, the mental and moral as well as the physical; (2) That the subject is one that must be inculcated in the child by observation and experiment.

It appeared, therefore, that one of the most useful subjects to which the Committee could devote this year's report would be the setting out of the essential points to be included in a curriculum for the practical training of teachers in school hygiene, and the following report has been prepared by the Sub-Committee for this purpose.

APPENDIX.

The members of the Sub-Committee appointed to consider 'The Teachers: What they should know of Physical, Mental, Structural, and Administrative Hygiene,' were imbued with the conviction that no class of the community has more widespread influence on the rising generation, and that it is, therefore, essential that all teachers alike, primary and secondary, be required to show proof of a practical acquaintance with the elements of hygiene. (1) In order, directly or indirectly, to train children of both sexes and all social grades to look at health questions with intelligent eyes, and to instil into them that sound knowledge of the rules which govern healthy life which is set forth as a fundamental principle of education by the Board of Education; (2) That the teaching profession may contribute its quota to the maintenance of good conditions of cleanliness, light, ventilation, and so forth in schools, to the provision of suitable equipment, and, above all, to the formation of good physical, mental, and moral habits among the pupils.

The subject being one of great scope and of some complexity, the Committee confined themselves to the definition of the minimum of information essential, in their opinion, for every teacher, male and female, leaving to a future occasion all consideration of the wider knowledge indispensable for specialist inspectors or instructors.

The appended scheme sets forth briefly this minimum standard of knowledge, which, however, to be employed to advantage, demands as a basis a previous study of general elementary science, including biology, to the extent set out, for example, in the Regulations and Syllabus for the Acting Teachers' Certificate Examination, 1904.

The Committee lay special stress upon this foundation, the possession

of which has been proved by experience to place the subsequent study of hygiene in its right light. Hygiene is then perceived to be a summing-up of other sciences, and of their application to the demands of daily life; theories can be verified by observation and experiment, while a new dignity is added to the routine duties of existence. Of equal importance is the inclusion of the elements of human physiology in the scheme on instruction. Without some comprehension of the functions of the body, and a realisation upon what conditions the adequate performance of these functions depend, the student of hygiene is exposed to two dangers: on the one hand he is disposed to a contemptuous attitude towards the details which, rightly regulated, promote vigour and well-being; on the other, he becomes a prey to fads and quackery bringing contempt on his cause and useless limitations to his powers and influence.

Further, it will be noted that prominence is given, wherever possible, to the study of the normal conditions of life, more especially of child life. Beyond recognition of certain abnormal signs, which should be as soon as possible reported to the medical officer, the teacher is not concerned with pathology. It is upon a high standard of health, not upon morbid departures therefrom, that the mind of school managers and scholars should be concentrated. Neither must the study of hygiene with teachers and children be confined to its personal, or even to its scholastic aspects. Too often its intimate bearing upon every relation and condition of life is overlooked—a serious matter in these days of the extension of local government. A permanent interest must be aroused in the means for promoting hygienic conditions among all grades of society. The teaching profession must realise that no child can be considered equipped for the responsibilities or for the stress of modern life without a sound knowledge of hygienic principles. In secondary schools it will be the governing classes of the immediate future upon whom the teachers' influence will be brought to bear; in primary schools, the practice of good habits under difficulties and of loyal co-operation with local health authorities must be emphasised; while in both the duties and responsibilities of citizenship, whether domestic or municipal, must be indicated by example and precept.

To this end the Committee desire to refer to the methods by which teachers should acquire the fundamental knowledge indicated.

Theoretical study of hygiene alone rarely stimulates practical application or awakens real conviction of its truths. Not alone should the teacher's course of study be planned upon practical lines, but the tests applied at its conclusion should be of a similar character. Power to observe and ability to suggest should be required, and personal acquaintance with appliances and methods, personal, domestic, and scholastic, should be demanded.

Hygiene for School Teachers

I. *Elementary Human Physiology in relation to Hygiene.*—Elementary structure of the human body. Phases of development. General survey of its various systems (nervous, circulatory, respiratory, osseous, muscular, digestive, and excretory), with special reference to the nervous system and organs of sense, including especially vision, nose breathing, and voice production.

II. *Food and Beverages.*—Nature and varieties. Standard diets as applicable to different ages.

III. *Personal Hygiene.*—The influence on personal development of cleanliness, clothing, and proportion of work, recreation and rest.

IV. *The Relation of the Individual to Life in Dwelling-house and School.*—Essentials of a healthy home—*e.g.* aspect, soil, altitude, precautions against dampness and ground air. Warming, ventilation, and lighting. Importance of sunlight, fresh air, and pure food. Sanitary appliances and house drainage. Household cleanliness and the removal of refuse. Mutual interests, duties and responsibilities of men and women.

V. *The Special Hygiene of Childhood.*—General knowledge of conditions influencing growth and development. Care and feeding of infants and young children. Influence of mental training on health and bodily development. Formation of habits.

VI. *School Hygiene.*—General arrangement of schools (grouping of rooms, playgrounds). Distribution and storage of water (filters, drinking-vessels). Ventilation ; floor-space, cubic space ; methods, natural and artificial. Warming (various methods). Lighting (natural and artificial). Drainage and sanitary appliances. School furniture (in relation to posture and school management). Books (printing-type). Decoration of schools. Physical conditions affecting health in schools. Periods of work and rest suitable to children of different ages. Recognition of naturally dull and defective children. School accidents ; simple methods of rendering first-aid ; the more obvious signs of fatigue, ill-health, and commencing illness. An elementary knowledge of infectious and parasitic diseases of symptoms of scarlet-fever, measles, small-pox, chicken-pox, diphtheria, mumps, ophthalmia, whooping cough. Methods of propagation and prevention. Nature and uses of disinfectants, of deodorants, and of antiseptics.

VII. *Public Hygiene.*—The relation of the individual to the community in matters affecting health.

There are several other branches of school hygiene which the Committee have set out for investigation, which they hope to include in a later report. The Committee therefore desire to be reappointed, and ask for a grant of 5*l*.

Studies suitable for Elementary Schools.—Report of the Committee, consisting of Sir PHILIP MAGNUS (*Chairman*), Mr. W. M. HELLER (*Secretary*), Sir W. DE W. ABNEY, Mr. R. H. ADIE, Professor H. E. ARMSTRONG, Miss A. J. COOPER, Miss L. J. CLARKE, Mr. GEORGE FLETCHER, Professor R. A. GREGORY, Principal GRIFFITHS, Mr. A. D. HALL, Mr. A. J. HERBERTSON, Dr. C. W. KIMMINS, Professor J. PERRY, Mrs. W. N. SHAW, Professor A. SMITHELLS, Dr. LLOYD SNAPE, Principal REICHEL, Mr. H. RICHARDSON, Mr. HAROLD WAGER, *and* Professor W. W. WATTS, *appointed to report upon the courses of Experimental, Observational, and Practical Studies most suitable for Elementary Schools.*

Nature Study the Foundation of Scientific Training.

WE regard the direct study of Nature as the sound foundation of all scientific training. The more training in scientific research the teacher has had the better. If he has only been getting up book-work in the

hope of passing examinations his influence may be less helpful. Where the teacher is not in sympathy with scientific methods of inquiry he cannot be expected to see how to put the children on the right road.

The Training of Teachers.

At present there are three agencies at work : (A) Saturday classes, (B) summer meetings (for existing teachers) ; (C) the training college course. A general elementary science course which includes some botany is now compulsory. Nature study, gardening, &c., can be taken as special subjects in the second year. Not many training colleges took up the subject in 1903, and even those were much discouraged by the magnitude of the work involved in the syllabuses which were attempted. In our judgment every training college should give such scientific instruction in the method of observation and experiment that the future schoolmaster would be put on the right track, and could later on work out his own subject. Teaching may be wholly opposed to the spirit we strive to inculcate if Nature study is treated as another, and a very cumbrous, subject to be got up for examination. The training college student is very heavily taxed ; he does not need more new subjects ; he does need to be taught the right method of going to work.

It is important that the instruction should not become stereotyped, and a course for teachers will gain in freshness if worked out anew each year. Great insistence should be laid upon the laboratory work, and all knowledge should be derived from the study of actual specimens. Mere text-book learning in the training college is like poison at the fountain-head.

Conditions of School Work.

In advising as to what work should be chosen, we must consider the conditions under which work in elementary schools is done. Some of these conditions are named in order that they may be altered ; others in order that advice may be practicable.

The size of the class, if too large, may make it difficult to organise any work of a new character—anything different from sitting at desks, listening, answering in chorus, writing from dictation, learning by rote, or working sums of a monotonous character.

The size of the class is a most important consideration if we wish the children themselves to carry on experimental work. Experience points to from twenty to twenty-four pupils doing practical work in a laboratory as quite enough for one teacher.

The country teacher does not feel the number of children so great a difficulty as their inequality of attainment, which makes it difficult even to teach more than a very few at once, and then only whilst others are marking time. If one teacher is called upon to teach a great variety of subjects, it is not reasonable to expect him to be an expert in each. Teachers should be encouraged to take as their special subjects whatever they can do best. Hence in the country we may find poetry in one school, history in another, gardening in a third.

Interest and Discipline.

Any novelty will arouse an evanescent curiosity in a school. We seek a permanent interest. Only on condition that their best efforts are expected can we hope to command the respect of our scholars and to maintain their keen interest. The teacher must know what he wants his pupils to do, and must find out whether they do it.

With new work it may be difficult to gauge their capacity, but every effort should be made to set definite work and to check it. There should be plenty for everyone to do, and plenty of interest in reserve. This means, for instance, that the supply of botanical material must be liberal.

The dictation of notes and the copying of diagrams from books or from the blackboard we condemn. We think that a good deal of time is now being wasted on dictation and copying, to the great prejudice of the name and fame of Nature study. The children should be asked questions; not told things; and their verbal answers may be used to draw up a description of the object before them. Afterwards they may try to do the like for themselves.

Drawing from natural objects is an admirable exercise in observation. If the first attempts of the class are disappointing the teacher may put his drawing on the blackboard before them, then rub it off, and ask them to try again from the specimen.

In training a class to manipulate experiments it is a good plan to ask children in turn to come up and try to do things before the class. In this way interest is stimulated, attention is drawn to probable mistakes, and the teacher feels when the class is ready to start individual work.

The Object-lesson to be Developed.

Any development of Nature teaching in the schools finds an easy starting-point in the object-lesson. But the object must be present if the lesson is to be real. If the elephant can only be represented by a picture, that is a reason for giving lessons about something else until it is possible to adjourn to a menagerie. Where flowers or stones are required let them be provided in sufficient quantity to give every child a specimen. Let these be distributed at once, so that the children may start with their own observations. This will require training, and the teacher will spend much time in discussing what is seen with the children.

A good way of ensuring that children do really observe is to ask them to make drawings from the specimens in front of them. Drawings can be more rapidly corrected by the teacher than written accounts: but written accounts should also be asked for. Whilst the drawing is being done there ought not to be any sketch on the blackboard which would serve as a guide.

Syllabus.

We have no syllabus to offer: there is no old syllabus to which we wish to adhere, nor any new one which we wish to put in its place. Any teacher who wishes for a syllabus will find that plenty of good ones have been published already by the Board of Education, and any teacher who has found the spirit in which to study Nature will be able to make a better syllabus for himself new every year.

Salvation will not come by any syllabus; and of every syllabus we would say:—

'This syllabus must be regarded as suggestive only, and not inclusive. Every teacher should be free to take part of the syllabus in detail rather than the whole superficially, and free also to go outside the syllabus. A syllabus may be useful as a humble servant, but it is a very bad master.'

The danger of a syllabus is lest the general topics prescribed, such as types of fruit, inflorescences, shapes of leaves, should be studied in advance of the real concrete plant. At the top of a botany syllabus we would put: 'This syllabus is intended to be suggestive only. All the work should be done from the actual living specimens. Accurate drawing should be an important feature. Even in large classes each pupil can have specimens of seeds, seedlings, flowers, &c. The pupil himself, if possible, should carry on the experiments. Outdoor work should supplement the work in the schoolroom. At all times plants should be studied as living things and not as dead material.' The rest of the syllabus may be left to the discretion of the teacher; so too with physiography. 'This syllabus should be illustrated by perpetual reference to the school district —indoors by experiments, out of doors by walks and excursions in the neighbourhood.'

The teacher who is planning his lessons some months beforehand will therefore require a calendar indicating what topics are likely to be in season. Gardeners' calendars are given away as advertisements by several firms of seedsmen. The current Whitaker, or better still the 'Nautical Almanac,' gives warning of impending celestial events. The average time of flowering of wild plants has been observed and indexed under the heading 'Phenology.' Several naturalists' calendars have been published. A farmer's year-book will be useful in the country. From these and from his own experience a teacher can compile a calendar of possible topics from which to choose his lessons.

The Seasons.

Several teachers of repute have recently drawn attention to the cycle of the seasons as the best ruling idea for the arrangement of any scheme of Nature lessons. And this we heartily endorse; there can be no better guarantee that the teaching will really be based on observation and experiment. In summer there is endless material. In winter it is more difficult to realise the opportunities of the moment; but the long nights favour astronomy, the bare earth suggests geology, the weather is always a source of anxiety, the frost without and fire within suggest lessons on heat and cold. As much as possible of the summer botany course should be unloaded on to the earliest weeks of spring whilst twigs are bare.

For younger children the topic for the object-lesson may very well be chosen from week to week, and may depend simply on what is most available; for the upper standards teachers will rightly wish to plan some more systematic course. But this plan should retain some elasticity in order to fit with the season. If the different stages of the opening chestnut bud are to be watched, they must be seized almost to a day, and yet one year they may open a fortnight before or after their date on the previous year. If the natural order *Rosaceæ* is being studied, we must remember to gather roses while we may.

JANUARY.
- Trees; twigs, branches, bark. Evergreens.
- Snow. Ice. Frost.

FEBRUARY.
- Bulbs, corns, tubers.
- Catkins.
- The lengthening day.
- Flooded rivers.

MARCH.
- Development of birds.
- Seeds and seedlings.
- Wind. Equinox. Spring tide. Full moon.
- View from hill-top. Making maps.

APRIL.
- Opening buds.
- Rain. Clouds.
- Flowers. Migrant birds. Birds' nests.

MAY.
- Experiments on plants. Rate of growth.
- Development of hen's eggs in incubator.
- Insect life. Bees.
- Dew.

JUNE.
- Experiments on plants. Assimilation.
- Butterflies.
- Pollination of flowers.
- Longest day. Solstice.
- Hay-making.

JULY.
- Plants.
- Caterpillars.

AUGUST.
- Heather.
- Chrysalis.

SEPTEMBER.
- Harvest.
- Seeds and seed-distribution.
- Equinox. Shortening days.

OCTOBER.
- Fruits. Germination of seeds.
- Falling leaves. Rain. Rivers.
- Planets and constellations.

NOVEMBER.
- Fog.
- Stones.

DECEMBER.
- Snow. Ice. Frost.
- Solstice. Shortest day.

The Living Plant.

The study of the living plant from the experimental side may be regarded as suitable for elementary schools. It satisfies the following important requirements :—

(i) It can be made experimental, and most of the experiments are such as can be repeated by the pupils. The experiments are often of a continuous character and afford some training in measurement and recording. It is wise to emphasise the quantitative side of many of the experiments.

(ii) The subject forms a connected series of lessons, the later work developing originally out of the earlier.

(iii) The experimental teaching in school is easily linked to the outdoor life of field and hedgerow with which country children are familiar. Again, it is readily illustrated by practical examples drawn from the work on the garden and on the farm, so that the children learn that school work may have a bearing on their after life.

While plant life forms a very generally suitable indoor subject for elementary schools, there should be a good deal of flexibility about the nature of the accompanying outdoor work. With some teachers gardening, with others field botany or geology, forms the accompaniment. The teacher should be encouraged to develop a speciality according to his own tastes and the advantages or restrictions of his locality. Thus for a school among osier-beds the natural history of the willow is an admirable subject.

Out of Doors.

It is now within the power of all elementary teachers to take the school out of doors for a lesson and to count it in the time-table. Inspectors are sympathetic, and it is frequently done.

Every syllabus that includes the shadow of a stick at noon or the nightly turning of the Great Bear about the Pole prescribes topics which it may be impossible to treat practically in lessons held at 2.30 in the afternoon. But this is just the reason why the routine of school work may suitably be broken to allow children to witness exceptional natural phenomena—a great flood, a high tide, or an eclipse of the sun—phenomena whose times of occurrence are not within our control.

In schools which possess a garden much can be done by the children in it. Simple experiments in assimilation, pollination, grafting, &c., can be tried. Where classification is studied the making of order beds by the children is a great assistance. When it is impossible to work in a garden, experiments may be carried on in window-boxes.

Excursions should be made to lanes and fields at all times of the year. Even in towns it is possible to study the branching of trees and unfolding of buds and to become familiar with the aspects of different trees in winter, spring, and summer.

To give definiteness to outdoor work some questions to be answered may be set before starting a walk, and answers to them written out afterwards.

Access to the Country.

Is it not possible that some city teachers, anxious to gain in Nature lore, would find that a few years spent in working at a country school would give them invaluable opportunities of studying things in the open which previously they had only heard of in lectures or read about in books?

The extent to which the children of the city may be usefully and economically transported to the country for purposes of education remains largely unexplored. The Sunday schools have demonstrated the possibility of taking large numbers into the country for a single day's outing. The Children's Country Holiday Fund and the various seaside camps held during the summer show how to arrange for a few weeks of holiday.

These arrangements have in view chiefly the great need for fresh air and holiday. But of definite, directed educational use of the country we hear little as yet. The question of extending the advantages of a country boarding-school education to the children of the poor is coming up for discussion. One large city is already casting longing eyes on the country schoolhouses standing empty during the holiday weeks whilst the town children pine for fresh air. A good deal might be done by hearty co-operation between city and county educational authorities. Schemes are mooted for sending out whole classes of city children under their own teachers for a few weeks at a country school. Some voluntary help and organisation, with special funds subscribed *ad hoc*, will probably be necessary to carry these schemes through.

We hear of one London Board school taking its scholars far afield, and a provincial Board school has shown what brilliant use may be made of the school journey. Some of our secondary schools are emphatic as to the usefulness of such journeys lasting more than one day. In Switzerland they have a much more recognised place as a part of general education. In our own elementary schools the difficulties are largely financial.

Incidental Teaching.

Those who are not naturalists by hobby may do much to encourage children by giving their moral support to the simple interests of the wayside. Children may be encouraged to bring curiosities with them to school. Many schools now have a rack of bottles to receive wild flowers picked on the way to school; a slate reserved for Nature notes, where the first scholar who sees a swallow may enter the fact. Pots of growing seedlings may occupy the window-sills. Aquariums are always interesting, and a caterpillar cage might be tried.

We hesitate to say much about school museums, unless they are to be annually burnt. Their use is in the making, not in the keeping. The course of instruction should be based upon specimens which may be handled freely, and, if necessary, pulled to pieces. But there is great use in a small glass case where objects brought in by the scholars may be placed at once and where every one may see them. This would become a 'collection of instructive labels illustrated by appropriate specimens.' But not for long; the contents must be changed more often than a shop window if interest is to be maintained.

Collections.

The collecting instinct is sufficiently strong at the ages we are discussing. The collector is often a naturalist in embryo; he is therefore to be judiciously led into the paths of progress. In certain directions—notably birds'-nesting—restraint more than encouragement may seem necessary; but numerous recent books illustrated by photographs of birds' nests show the possibility of teaching children to watch without destroying. The general line is to wean a boy gently from mere collecting to collecting with a purpose; to collecting and observing, and then to the collection of observations in a notebook kept for the purpose. Collecting is a great help to accuracy of observation, and the boy who brings back a collection of pebbles from the seashore or of grasses from a hayfield will know far more about what he carries in his hand than a schoolfellow who has never troubled to pick up anything. Children may be encouraged to try how many different sorts of wild roses they can find along a country lane, and to write notes on their differences.

The collecting instinct is a great motive power, if rightly directed. It should be used to solve special problems. And if prizes are offered, they need not be for the largest or best collection of wild flowers, but for collections illustrating insect pollination, or seed dispersal, or climbing plants.

Books.

We agree in thinking that books should only play a very subordinate part in teaching intended to bring elementary school children into first-hand contact with facts.

For boys over fourteen, attending a secondary school, ready to do some evening preparation and coming from homes where the cost of books is not too overwhelming, the answer would be different; but the caution that their first introduction should be to the real thing becomes even more important. We do not suppose that, at the ages of twelve to four-

teen, children can usefully be set to learn lessons from any book which has not previously been explained to them.

A natural history reading-book should never be accepted as Nature study in school. Many a teacher, feeling his own ignorance, may be glad to use such a book to rouse an interest in what he feels himself incompetent to teach. There are many such books which might suitably be put into school libraries or given as prizes; to name dead authors only, we might mention Wood's 'Common Objects of the Country,' Waterton's 'Essays on Natural History,' White's 'Natural History of Selborne,' and Buckland's 'Curiosities of Natural History.'

Voluntary Help.

It is just in the country schools, where it is impossible to expect the professional teachers to be specialists in every department at once, that we are most likely to appeal successfully to local residents for help. Leave from the squire to see his new agricultural machinery, a visit to any well-kept flower garden or apiary, help to the pupil-teachers in naming flowers, gifts of books to the school library—any of these would be a great assistance. The difficulties are often personal and real—the teachers know best when the children are interested and when they are tired—and all help extended to the teachers gets through to the children. We want to enlist for the elementary schools the same kind of help from enthusiastic governors, parents, old scholars, and friends which has already done so much for the secondary school. There is already a Society for encouraging work in this direction—Secretary, Miss Isabel Fry, 8F Oxford and Cambridge Mansions, N.W.

Local Natural History Societies.

The Committee of the Corresponding Societies inform us that they are anxious to know how they can best assist Nature study in schools.

We suggest for their consideration—

(i) There are many members of these societies who are also members of the local education authorities, who could therefore do much to bring the best ideals of teaching to the knowledge of their colleagues, and whose personal influence would lubricate any organisation or arrangement that might be necessary to carry out these ideals—for instance, in getting flowers from the parks supplied to the schools.

(ii) The present is an opportune moment for these societies to bring the advantages of membership to the knowledge of elementary school teachers. They need help in new studies, and the personal goodwill and companionship of local naturalists will often be useful.

Schools for Educational Experiments.

In advising as to the best work for public elementary schools we ought to look for ideals among the 'preparatory schools,' where boys of the same ages are being taught under conditions which ought to favour individual initiative and enterprise. These schools are dominated by the entrance and scholarship examinations of the public schools. We are glad to notice that Elementary Science has been made an optional subject in the new 'Common Examination for Entrance to Public Schools.'

It is of great importance that any such paper should encourage great elasticity of treatment in the schools—as might be done by giving some choice of questions—and still more important that the questions should involve direct observation of Nature, a personal acquaintance with simple manipulations, and a thoughtful consideration of everyday occurrences. Arithmetic, mechanics, and botanical bookwork we do not commend as either experiment or observation.

Criticisms.

Some serious defects which have been noticed in Nature study teaching as at present conducted are :—

(i) An attempt is made to cover too much ground, hence experiments and measurements are shirked because they take time and involve preparation on the part of the teacher. Experiments are described instead of performed, and a drawing on the blackboard takes the place of realities. This is the commonest and most vicious defect in such teaching.

(ii) Unsuitable subjects are often taken, especially with the idea of being practical. It is no use dictating notes on haymaking to a class when there is no opportunity of seeing the process carried out.

(iii) On the other hand, there is a great lack of system. A lesson on opening buds is followed by one on tadpoles or on the motions of the moon. The topics are all in season in March, but for Upper Standards we think the course should become more systematic.

(iv) When a definite course is chosen it is often overloaded with classification. The teacher seems to have the fear of a possible examiner before him, and is afraid to omit anything. Sciénce is too often supposed to consist of big words. 'Amaryllis, fruit, a bilocular loculicidal inferior capsule' need not appear in the notebook of a boy of thirteen.

Influence of Examinations.—Report of the Committee, consisting of Dr. H. E. ARMSTRONG (*Chairman*), Mr. R. A. GREGORY (*Secretary*), the Bishop of HEREFORD, Sir MICHAEL FOSTER, Sir P. MAGNUS, Sir A. W. RÜCKER, Sir O. J. LODGE, Mr. H. W. EVE, Mr. W. A. SHENSTONE, Mr. W. D. EGGAR, Professor MARSHALL WARD, Mr. F. H. NEVILLE, Mrs. W. N. SHAW, and Dr. C. W. KIMMINS.

ALTHOUGH there is a strong consensus of opinion as to the evil effects produced by the existing system of examinations, very diverse views are held as to the remedies which should be introduced ; and it may not be easy to secure acceptance of modifications which would make it possible to direct the education afforded by schools into really effective channels. Success can only be secured by the growth of a sound public opinion on such matters. Meanwhile there are many forces at work tending to bring about improvement. The conditions laid down by the Board of Education for admission to the register of teachers are likely to affect both teachers and schools in no slight degree : by leading those who intend to take up the work of teaching to undergo special training for their office, and by bringing schools under inspection in order that they may secure recognition. Moreover, many of the new education authorities are displaying marked interest in the problems of education.

The question of examinations has entered upon a new phase, and a more hopeful situation has been created by the issue, on July 12 last, by the Board of Education, Whitehall, of suggestions for a system of *school certificates* which have been submitted to the Board by the Consultative Committee. It is to be noted that the Board refrain, in offering the scheme for public criticism, from the expression of any view as to the desirability or feasibility of the proposals—and are not at present committed to any action in the matter.

The Scotch Education Department has long granted leaving certificates in single subjects; since 1902 it has given certificates for success in groups of subjects. There is a tendency more and more to correlate examination with inspection, and to call in the services of the teachers as well as to take into account the work done by scholars during their school career.

Examinations are held under the Central Welsh Board of Intermediate Education, and upon them certificates are granted which meet with a limited amount of recognition in lieu of other examinations. The majority of the members of the Board are actively engaged in the management of the schools under the jurisdiction of the Board, the headmasters and headmistresses having special representation. It is said to be the aim of the Board that every school should, as far as possible, be examined on a curriculum of its own choice; schools may accordingly, in each year, submit alternatives to the syllabuses of the Board in all or any of the subjects.

Some of the examinations held by the Oxford Delegacy of Local Examinations, the Cambridge Syndicate of Local Examinations, and the Oxford and Cambridge Schools Examination Board, serve the purpose of leaving certificates in a measure, inasmuch as they carry exemption from certain qualifying examinations; but these examinations are conducted by boards unconnected with the schools, and do not take into cognisance the work of the scholars.

The University of London has recently put in operation a scheme for the award of leaving certificates to scholars in schools under inspection approved by the University.

In none of the English examinations is the opinion of the teacher of the pupil's abilities taken into account in the manner customary in the the German Abiturienten-Examen. An interesting account, by Professor M. E. Sadler, of the manner in which this examination is conducted in the secondary schools of Prussia, will be found in Vol. V. of the Report of the Royal Commission on Secondary Education, 1894.

In the United States certain of the universities have taken a step far in advance of European practice by admitting (without examination) pupils from recognised high schools.[1]

To facilitate comparison, the proposals of the Consultative Committee are printed hereafter in full, together with notes on the Scotch leaving certificate, the London University scheme, and the remarks made by Professors.

[1] Principal Reichel and Dr. Gregory Foster in the Mosely Commission Report on the American accrediting system.

Proposals of the Consultative Committee of the Board of Education for a System of School Certificates.

THE following letter, addressed by the Secretary of the Consultative Committee to the Secretary of the Board of Education on June 1, 1904, explains the origin of the proposals :—

'I am directed by the Consultative Committee to forward the following statement in answer to the Board's reference of 20th March, 1902. The Committee think it may be well to give a short account of what has taken place in connection with that reference.

'Towards the end of 1901 the Board of Education received a letter from the General Medical Council, forwarding a memorial addressed to that Council by the Head Masters' Conference. The memorial had also been sent to—

'The Pharmaceutical Society, the Incorporated Law Society, the Royal Institute of British Architects, the Institution of Civil Engineers, the Institute of Actuaries, the Institute of Chartered Accountants, the Society of Accountants.

'Its object was to draw attention to the grave inconvenience and waste of time caused by the multiplicity of examinations for entrance into professions. It pointed out that five of the bodies named held examinations of this kind themselves, which, although substantially identical in standard, were altogether diverse in the details of their requirements. The effects of this diversity were very serious, not only to schools, by rendering it impossible for boys working for the different examinations to be taught together, but also to the education of the boys preparing for the examinations, by depriving them of regular class instruction during their preparation. It was also observed that although these five bodies, as well as the others which do not examine, publish lists of examining bodies whose certificates they accept, the relief given was very partial, as no two lists were the same.

'The Head Masters' Conference suggested the institution of a single examination, to be held at centres three times a year ; also that if possible a list of equivalents to this examination should be arranged for, to be adopted in common by all the bodies. They proposed that a conference should be held between representatives of the Councils concerned, of the Universities, the Board of Education, the Head Masters' Conference, and the Incorporated Association of Head Masters for the purpose of devising a scheme to put their suggestions into effect.

'The Board referred the correspondence to the Consultative Committee for their advice. Some specific questions in relation to the reference were framed by the Board, and the Committee were asked to answer them. On an examination of the matter, after collecting the necessary information, the Committee found that it was impossible for them to answer the Board's questions in a really satisfactory way without formulating their views on the best method of testing the instruction given in a secondary school, as it appeared to them that this was at the root of the whole subject. On this account it appeared to the Committee that the first step required was to ascertain the general attitude of those whom a change in the present system would chiefly affect—namely, the

Universities and the teaching profession—as well as that of professional bodies concerned. The Committee therefore suggested that the reference originally made to them might be extended so as to include the general question. The Board, after conferring with the Committee, authorised them to make all necessary inquiries. The Board promised to give their careful consideration to any scheme which might be drawn up as a result, only stipulating that it should be clearly understood and explained that they did not engage themselves to take any action, if action on their part was proposed, and must not be regarded as committed to an endorsement of any proposals made by the Committee. Although sympathising in the desire of the Committee to reduce the number of examinations, the Board were obliged to view the question not on its own merits alone, but in connection with the whole of their educational policy.

'Under the Board's sanction the three undermentioned Conferences were arranged and held by the Committee during the year 1903 :—

'(1) Held on the 8th and 9th May with representatives of the following Universities :—

'Birmingham University, Cambridge University, Durham University, London University, Oxford University, Victoria University.

'(2) Held on the 2nd July, 1903, with representatives of the following associations of teachers :—

'Head Masters' Conference, Association of Head Masters, Association of Head Mistresses.

'(3) Held on the 4th December, 1903, with representatives of the following professional bodies :—

'Society of Accountants, Institute of Actuaries, Royal Institute of British Architects, Institute of Bankers, Institute of Chemistry, Institution of Civil Engineers, Institution of Electrical Engineers, Institution of Mechanical Engineers, General Medical Council, Pharmaceutical Society.

A representative from the War Office and one from the Civil Service Commission also attended this Conference.

'At these Conferences a provisional scheme for the institution of school certificate examinations, which had been drawn up by the Committee, was used as a basis of discussion. The views expressed at the first Conference gave ground for making certain modifications in this scheme; the modified scheme was discussed at the two last Conferences without alteration.

'Two more Conferences of a similar character were held in the early part of the present year.

'(4) On the 25th of February with representatives of the College of Preceptors.

'(5) On the 25th of February with representatives of the Private Schools Association.

'The Committee have also had the advantage of hearing the evidence of Mr. J. Struthers, of the Scotch Education Department, who gave them some interesting information relating to the working of the Leaving Certificate system of the Department.

'After careful consideration of the opinions expressed at these Conferences and of the present circumstances of secondary schools in the country, they have drawn up the annexed scheme containing proposals for a system of school certificates for England.

'In framing the proposals due consideration has been given to the position of the various bodies by which the work of examination is now carried on, both in relation to the present and to the future.

'The Committee have considered a very large number of minor points on which they do not here report, as they believe that a broad outline of their proposals not too much cumbered with details is, for the present at any rate, what is required. They submit these proposals in the confident belief that the adoption of the plan suggested would result in very substantial benefits to secondary and higher education in this country.'

The following are the proposals of the Committee :—

The Consultative Committee are of opinion :—

(1) That, with the object of diminishing the multiplicity of examinations affecting secondary schools, and of providing a test of adequate general education which may be widely accepted, a general system of school certificates is desirable.

The well-known term 'Leaving Certificate' has been purposely avoided because it is to some extent misleading and is not unfrequently misunderstood.

(2) That it is not desirable that examinations for such certificates should be conducted by means of papers set for the whole country from a single central organisation.

This clause must be read together with clause (6). It will be found that it is not the intention of these proposals to ignore the influence of the State in the supervision of a general system of examinations. On the other hand, it is important to prevent the evils which would almost certainly arise from the State having the sole responsibility in the matter. The desirability of bringing the examining body into closer relation with the teacher being recognised, it is obvious that in dealing with a population of more than 30,000,000 and a large number and great variety of schools, this object can only be effectively attained by the establishment of more than one examining body. The success of the Scottish and Welsh systems seems to be largely due to the limited number of schools with which they have to deal.

(3) That such examinations should be controlled by a recognised examining body, which should be either (1) a University, or (2) a combination of Universities, or (3) an Examination Board representative of a University or Universities and of the local authorities which are prepared to co-operate with them. It is desirable that whatever the examining body may be, teachers of schools should, where possible, be represented, and with regard to (3), that every such Board should contain a large academic element.

The proposal to form in some cases Boards representing local authorities and teachers in the schools as well as Universities may afford an opportunity for making an important new departure. Those local

authorities especially which aid the schools and may perhaps pay the examination fees may be glad to be associated with a neighbouring University. There is further a growing body of public opinion in favour of associating the teachers in the schools with duties of this kind.

No general rule can be laid down requiring a school to be examined by a particular examining body. It may often be desirable that a school should be examined by the University or Board of the district in which it is situate. On the other hand a school may prefer to preserve or to create a connection with one of the Universities of Oxford, Cambridge, or London. It is recognised that it would not be desirable, if it were possible, to disregard the non-local character of these Universities, or the position which their examinations occupy all over the country. The proposals are based on the assumption that it will ultimately be best for the secondary schools which are maintained or largely aided by local authorities to look to provincial examining bodies for the organisation of their examinations, and it is not improbable that local authorities may prefer their doing so ; but in any case there will be a period of transition during which the new system and the existing University examinations will run side by side for all classes of schools, and the higher secondary schools will doubtless always retain complete liberty in the choice of their examining body.

(4) That recognition of these examining bodies should mean recognition by the Board of Education, acting on the advice of the Consultative Committee.

(5) That the following conditions should be required from schools which present candidates for school certificates :—

(*a*) Periodical Inspection. Whether this inspection be conducted by officers of the Board of Education, or by a University or other organisation recognised under Section 3 of the Board of Education Act, 1899, the report of the inspection should be communicated to the examining body.

(*b*) The communication of the course of studies pursued in the school to the examining body.

That an examining body should be at liberty to decline to examine a school if the result of the inspection has not been, in their opinion, satisfactory ; or if the course of studies is such as they are not able to approve.

It is considered that in this connection inspection and examination should be treated as complementary one to the other. Inspection is required, in the first place to enable the examining body to judge whether a school is fitted to be admitted to the benefits of the system ; but it is also required to enable the examiners to understand the aims and characters of the different schools, and so, on the one hand, to prevent the examination from becoming mechanical and rigid, and on the other to check any tendency in the school to direct its efforts too exclusively to success in the examination.

(6) That a Central Board should be established for England (excluding, for the present, Wales and Monmouth), consisting of representatives from the Board of Education and from the different examining bodies, whose duty should be to co-ordinate and control the standards of these examinations, to secure the interchangeability of certificates, and to consider

and as far as possible to adjust the relations of the examining bodies and their spheres of external action.

Although absolute identity of standard between examinations conducted by different bodies and in different places may be an impossible ideal, practical equivalence can probably be secured. Further, more than one combination of subjects may be held to represent a good general education. It will be the duty of the Central Board to see that a sufficient minimum standard is maintained in each subject, so that certificates including these subjects, wherever given, may possess a generally recognised and interchangeable value, and further, that these certificates represent in each case a good general education.

(7) That the Board of Education should constitute this Central Board as soon as, in their opinion, a sufficient number of recognised examining bodies have signified their willingness to be represented thereupon, and should take all steps that may be necessary to procure the acceptance of the certificates by the professional bodies.

(8) That since an examination held with the co-operation of the school in which a scholar has been taught is more likely to lead to a just estimate of the knowledge which he possesses than one held entirely by an outside body, the examination should be conducted in each school by external and internal examiners, representing respectively the examining body and the school staff.

(9) That the course of the work pursued by a scholar during his school career should be recorded and reported on by his teachers, and that this school record and report should be available for reference in deciding his fitness or unfitness to obtain a certificate.

The suggestion here is that an examiner, in any case in which he desires to do so, should be able to judge of the character of a candidate's school career. The school records and reports need not be of uniform pattern. What is required is that such materials shall be accessible as will enable an examiner to judge whether the scholar's school career has been satisfactory or not. These materials will include, at the least, the curriculum of all the classes which a candidate has attended, a note of the time he spent in each, and periodical reports of his industry, regularity, and progress.

(10) That the headmaster or headmistress of the school should certify that the candidate has received instruction during the necessary period, and is, in his or her opinion, fit to enter for the examination.

(11) That the external examiner or examiners should have control of the examination, and should have a veto on the passing of any candidate.

(12) That the papers should be set by the external examiner, after consultation with the internal examiner.

This consultation does not necessarily involve a series of personal interviews previous to the examination. Full information as to the courses of study pursued by the candidate would in the first instance be supplied to the examining body for the information of the external examiner. The books read, whether in English, classical, or foreign literature, and the courses of history or geography studied, the practical work done, &c., would thus be reported. The internal examiner, also, would suggest series of questions, or indicate points upon which, in his

opinion, questions should be set; and in general the two examiners would correspond on the subject-matter of the examination paper. The paper should, however, be finally made up by the external examiner on his own responsibility.

(13) That the allocation of work in reading and marking papers should be determined by the examining body, provided that papers which are near the minimum pass mark should be considered by both examiners.

(14) That oral and practical examinations should be conducted by the external and internal examiners acting in concert, who should, subject to Section 11, jointly assess the mark for each candidate in this part of any examination.

(15) That in language examinations no special books should be prescribed, but that passages should be included from the books used in the school as well as unseen passages. That an oral examination should always be held in the case of modern languages.

(16) That there should be a senior certificate for pupils who have received not less than four years' instruction in a school or schools accepted for examination under Section (5).

That there should be a junior certificate limited to pupils under sixteen years of age who have received not less than three years' instruction in a school or schools accepted for examination under Section (5).

With reference to the number of years of instruction required, it will be desirable at first to give some latitude to the Central Board.

(17) That no certificates for honours or marks for special distinction should be given, but that it should be open to the examiners to recommend the award of scholarships within a school or group of schools when called upon to do so.

(18) That scholars who are in a school which, in the opinion of the Board of Education, is unable to conform to these regulations, might be allowed to enter for the examinations under special regulations approved by the Central Board.

The Leaving Certificates of the Scotch Education Department.

These certificates are not awarded on the results of an examination alone, but, in addition, the Department require to be satisfied that the course of instruction followed by candidates has been of adequate range and quality, and that proper attention has been paid to those elements of the curriculum which do not admit of being tested by examination papers.

This is ascertained by inspection of schools where candidates are at work, including oral examination by the inspector.

A Leaving Certificate examination is held annually at a number of centres, usually the schools from which candidates are presented.

In the case of subjects other than science and drawing, the examination is a written one held in June at all centres simultaneously.

The papers in any subject are the same at all centres.

There are three standards in the written examination: Lower, Higher, and Honours Grade.

The examinations in science and drawing are based more directly on the curriculum and work of schools, care being taken to preserve uniformity of standard.

The science examination is chiefly oral and practical; at that in drawing, previous work at the school is taken into consideration. Both are conducted by inspectors or persons specially appointed, and are held at the schools themselves at convenient dates towards the end of the summer session.

There is only one grade of examination in science and drawing.

The Leaving Certificate examinations in these various grades are open to the pupils of all schools under the inspection of the Department—*i.e.* practically all schools, elementary or secondary, in Scotland; but the Leaving Certificate proper, subsequently referred to, is intended solely for pupils who do not propose to return to school.

Two kinds of certificate are issued :—

(1) The Leaving Certificate (proper).
(2) The Intermediate Certificate.

The certificates (*a*) show the subjects and grades of subject in which the examination has been passed; (*b*) do not bear any special endorsement of ability to converse in a modern language; but no certificate for modern languages is issued to the pupils of a school in which the inspector reports that this side of the instruction has been neglected, or in which pronunciation has been found to be unsatisfactory.

The Leaving Certificate (proper) is intended to mark the completion of a full course of secondary education. It is limited to pupils above seventeen years of age on October 1 in the year in which they pass the last of the written examinations that would fall to be recorded on the face of the certificate. Applicants must also have received instruction at some recognised school for not less than four years. It may be regarded as about equivalent to Matriculation Standard, in some respects it is higher.[1]

Candidates must pass in four subjects of the Higher Grade Standard or in three of the Higher Grade Standard and two of the Lower. English and Mathematics are compulsory. At least one language other than English must be taken.

Science only counts as one subject.

The Intermediate Certificate is intended to meet the case of schools which are not able to retain their pupils long enough to enable them to complete a full course of secondary education. It is limited to pupils above fifteen years of age who have received instruction at some recognised school for not less than two years.

Candidates for the Intermediate Certificate must have passed in four subjects, at least one of these subjects being in the Higher Grade Standard. Otherwise the conditions are similar to those prescribed for the Leaving Certificate (proper).

The Leaving Certificate and the Intermediate Certificate are accepted in lieu of preliminary examinations by the following bodies :—

The Lords of Council and Session (for the purposes of the Law Agents Act);
The University of Oxford;
The University of Cambridge;

[1] It is acknowledged to be higher than the Preliminary Examination of the Scotch Universities, and in some subjects approximates to the standard required for the University degree.

The Joint Board of the Scottish Universities for the Preliminary Examination ;
The General Medical Council ;
The Royal College of Surgeons of Edinburgh ;
The Pharmaceutical Society of Great Britain ;
The Society of Solicitors before the Supreme Courts ;
The Chartered Accountants of Scotland ;
The London Chamber of Commerce ;
Girton College, Cambridge ; and
Royal Holloway College, Englefield Green, Surrey.

Generally these equivalents take account only of the *individual* subjects recorded on the certificate. All *Leaving* Certificates would be accepted, but candidates holding *Intermediate* Certificates only might also be accepted on account of the individual passes secured by them.

Detailed information with respect to these certificates is given in the Annual Report of the Committee of Council on Education in Scotland, 1901–2, *vide* pages 383–407 and pages 315, 316.

University of London.

Regulations for the School Examination (Matriculation and Higher Standard) and for the School-leaving Certificate.

(1) The University is prepared to award School-leaving Certificates under the following conditions to pupils on leaving school who have satisfied the following conditions :—

(i) Have pursued an approved course of study for a period of years at a school under inspection approved by the University.

If the school is not actually inspected by the University within the year, or if the school has never been inspected by the University, it will be required as a condition of entering candidates for the School-leaving Certificate to pay a fee of 5*l.* This will cover the visit of the inspector to hold an oral examination, and for the present this will be accepted by the University as satisfying the above condition as to inspection.

(ii) Have in the School Examination attained a standard at least equal to that of the Matriculation Examination in the requisite subjects, have satisfied an oral test in Modern Languages and in any other subject that may be thought desirable, and have passed in accordance with the Regulations of the Matriculation Examination affecting the subjects to be taken. (See extract from Matriculation Regulations, p. 372.)

It is not contemplated by the University that pupils should necessarily, or even generally, leave school as soon as they have passed the School Examination (Matriculation Standard). *The School-leaving Certificate will not be awarded until the pupil has qualified to be registered as a matriculated student of the University and is about to leave school.*

(2) Any school desiring to present pupils for the School-leaving Certificate will be required to submit to the University a general statement of the complete course of instruction given in the school, and also the curriculum of study pursued by the candidates. In judging the adequacy of the curriculum for the purpose of the certificate, the University will take into consideration its suitablility to the school and pupils concerned

having regard to the width and completeness of the course of study as a whole and not merely to its compliance with the requirements of the Matriculation Examination. In consequence the University may, in arranging the Scheme of Examination with any school, limit the options as compared with those open to individual candidates at the Matriculation Examination, and may, with the consent of the authorities of the school, require additional subjects or papers to be taken.

(3) The School Examination may be conducted either—

(*a*) By means of the Matriculation Examination Papers or equivalent papers, together with any additional papers of the same standard that may be found necessary in relation to the school curriculum, or

(*b*) By Special Advanced Papers of Higher Standard set for particular schools, groups of schools or groups of candidates in a particular school;

together with, both in the case of (*a*) and in that of (*b*), an oral examination in certain subjects, especially Modern Languages.

(4) The Special Advanced Papers will be set in one or more subjects in cases where the University is of opinion that adequate evidence has been adduced that the standard attained by the school in such subject or subjects is markedly higher than that of the corresponding subject of the Matriculation Examination.

(5) Any pupil in a school at which Special Advanced Papers are set for the School Examination will, if unusual merit is displayed in those papers, have a mark of distinction affixed to his name, indicating the subject or subjects in which he has distinguished himself. In this case the certificate shall be described as a Certificate with Distinction in the subject or subjects in question.

(6) The five subjects required to satisfy the Matriculation Regulations must be taken at one and the same time, but a candidate who in any one examination has passed in all the subjects required to make his certificate equivalent to the Matriculation Examination, shall at any subsequent examinations be allowed to take such additional subject or subjects, or such Special Advanced Paper or Papers, as the authorities of the school may approve. The fact that he has passed in such additional subject or subjects or Special Advanced Paper or Papers, together with any marks of distinction he may have obtained, shall be indicated on his certificate or in an appendix thereto.

(7) Any pupil who has passed the School Examination (Matriculation Standard) and who has thereafter passed an Intermediate Examination while still a pupil at the school, shall be entitled to have this fact endorsed on his certificate.

(8) Any pupil who has passed the School Examination with a view to the School-leaving Certificate, will be entitled although not leaving school to be registered as a matriculated student of the University without further examination or payment, provided he has attained at least the age of sixteen years.

(9) Any pupil who has not entered for all of the subjects required, or has not passed the examination in all of them, shall be entitled to have his attainments set out on a document which will state the subjects in which the pupil has reached the approved standard, but this shall in no case be accepted in lieu of any part of the Matriculation Examination, or of the School Examination with a view to the School-leaving Certificate.

(10) The course of study pursued by the pupil at the school, his age, the period during which he has attended, and the subjects in which he has reached the standard required by the University, will be stated on the School-leaving Certificate, which shall only be presented to him when he actually leaves the school.

(11) Any pupil at a school inspected by the University who—

(*a*) Distinguishes himself in any form of manual, artistic, or technical skill; or

(*b*) Displays any form of general or special capacity not tested by the examination;

may, if it is desired by the authorities of the school, have a note to this effect added to his certificate.

If desired, the University will undertake to examine in Music and Drawing, and to indicate on the certificate proficiency in these subjects.[1]

(12) In cases where the Matriculation Examination Papers are used for the purpose of the School Examination (Matriculation Standard) the examination will be held on the same days, at the same hours, and under the same conditions as an ordinary Matriculation Examination, and the school may for that purpose become a subordinate centre for the examination, provided there shall be a sufficient number of candidates from the school, and certain conditions are fulfilled. The University will be prepared in order to meet the wishes of a school or group of schools, to hold a School Examination at a time other than that of the ordinary Matriculation Examination or the time fixed for a regular School Examination, provided the whole cost of such special examination is borne by the school or group of schools.

(13) The University has appointed a small Board of Inspectors, consisting of persons largely experienced in teaching, who act as Moderators for the Matriculation Examination, and are at the same time responsible for maintaining the standard of the School-leaving Certificate.

(14) The University is prepared to co-operate with local authorities not only by undertaking the inspection of schools which are under the control of such authorities, but also by reporting on the result of the School Examination with a view to the award of any scholarships and exhibitions offered by such authorities. A small additional fee will in this latter case be charged to meet the cost of a second revision of the papers by the University Examiners, with a view to the candidates being placed in order of merit.

The University will offer to the Governing Bodies of those schools at which Special Advanced Papers are taken similar facilities for the award of school scholarships and prizes.

(15) The authorities of any school at which the School Examination either of Matriculation Standard or Higher Standard is to be held, should obtain from the Registrar of the University Extension Board a form of entry for each candidate, which must be returned duly filled in six weeks before the date on which the examination will begin, accompanied in each case by a certificate of birth or other evidence as to age. At the same time the fee of 2*l.* for each candidate must be paid, unless the school has entered into an arrangement with the University as to the

[1] Fuller particulars as to Music and Drawing will be found in the Regulations for the Inspection of Schools.

inclusive payment covering inspection and examinations referred to in the Regulations for the Inspection and Examination of Schools.

(16) Each candidate for the School Examination either of Matriculation Standard or Higher Standard will be required to pay a fee of 2*l.*, and, if successful, his name will, upon the production of satisfactory evidence that he has attained the age of sixteen years, thereupon be placed upon the Register of the University as a matriculated student.

An additional charge of 2*l.* will be made for each Special Advanced Paper set at a school. If two, three, or four schools are associated in taking the same Special Advanced Papers the fee of 2*l.* per paper will be divided between them. If more than four are so associated each school will be charged 10*s.* for every Special Paper.

A school not inspected within the year by the University will be required, as a condition of entering candidates for the School Examination, to pay a fee of 5*l.*[1] and to be responsible for the fee and expenses of the superintendent appointed to supervise the examination, should the University think it necessary to appoint one, and a sufficient number of candidates must be entered or the equivalent in fees be paid. If a school, however, is at the same time inspected by the University, the inspection fee will cover the above charge of 5*l.*, and no limitation will be placed upon the minimum number of candidates required to be entered. In this case also the oral examination of candidates will be conducted by the inspectors as a part of the inspection, and the inspectors may take into account the results of the School Examination in making their report upon the school.

Extracts from the Matriculation Regulations.

Candidates shall not be approved by the Examiners unless they have shown a competent knowledge in each of the following five subjects, according to the details specified under the several heads :—

(1) English. One paper of three hours.

(2) Elementary Mathematics. Two papers of three hours each.

(3) Latin, or Elementary Mechanics, or Elementary Physics (Heat, Light, and Sound), or Elementary Chemistry, or Elementary Botany. One paper of three hours in each subject.

(4) and (5) Two of the following subjects, neither of which has already been taken under Section (3). One paper of three hours in each subject. If Latin be not taken, one of the other subjects selected must be another Language from the List, either ancient or modern :—

Then follows a list of subjects in the various departments of study.

In addition to the list of Science Subjects there given, 'General Elementary Science,' *including practical work*, may be taken for the School Examination by schools possessing adequate facilities for practical work.

The American Accrediting System.

The following is the account given by Principal Reichel in the Mosely Commission Report :—

'The accrediting system is the method by which the Universities in the Middle West and West admit pupils from "accredited" or recognised

[1] This will cover the cost of the oral examination.

High Schools without entrance examination. It began in 1872 at the University of Michigan (Ann Arbor), and was the result of the drawing together of the State University and the State High Schools for the purpose of mutual support. At first a committee of the professors paid an annual visit to the school and conducted a complete inspection and examination. Soon this visit became triennial, and was confined to inspection; finally, as the work grew still heavier, it was taken over by a special University inspector, who reported to the heads of the departments in the University. The inspector visits the schools *without previous notification*, and his inquiry is exhaustive. If his report is satisfactory the High School is "accredited" for three years. Graduates from such an "accredited" school are admitted to the University without examination if certified by the principal of the school as having studied the subjects required by the University and recommended by him as capable of pursuing University study with profit. The responsibility is thus thrown on the school, the reputation of which depends on certified students proving satisfactory, for a certified student breaking down is liable to be sent back. So strongly do the schools feel the responsibility that numbers of students go up and pass the entrance examination whom their principals have refused to certify. The advantages claimed for this system are:—

'*For the University.*—(1) That the standard of the certified student is higher. This is shown by the figures of the first nine years' working of the system, based on 1,000 students and 10,000 acts of examination. (2) The attendance is increased owing to the interest aroused amongst the High School pupils by the visit of the University inspector.

'*For the Schools.*—The visits of the inspector are a powerful stimulus (i) to the teachers, with whom he holds conferences, discussing difficulties and making and hearing suggestions; (ii) to the pupils, in whom it arouses a spirit of inquiry about the University and lends dignity and importance to their work; (iii) to the localities, which think much more of their school and are more ready to support it if it bears the stamp of University approval. Finally, it provides governing bodies with an easy test of school efficiency.

'The number of schools accredited by the University of Michigan, originally sixteen, has now risen to 250. As compared with the rival system of entrance by examination only, which is maintained by the Eastern Universities, it possesses the great educational advantage of leaving the schools a freer hand in the choice of curriculum, and the still greater one of removing the well-known evils which attend the preparation by one set of men for examinations conducted by another set. On the whole the private schools, so far as I have been able to learn, favour the examination method, on the ground that it is a stimulus to work and provides a useful standard. At a conference held at Baltimore in 1902 by the colleges and preparatory schools of the Middle States and Maryland the subject was debated at length. Five of the speakers were against the examination system, including James E. Russell, the Dean of Columbia Teachers' College, New York, and only two in favour of it. The balance of argument was overwhelmingly against, the main points being:—

'(1) That the head of a school must be a better judge of the capacities of his pupils, whose work he has seen for years, than an examiner who views it on a single occasion and under normal conditions.

'(2) That the preparation for outside examinations has a ruinous effect on the system of instruction.

'The arguments of its supporters, on the other hand, implied incapacity, or slackness, on the part of the school teacher.

'In Minnesota the work of inspection is carried out, not by the University, but by a State High School Board, of which the University president is chairman, and which appoints a High School inspector. This system is closely parallel to that of the Central Welsh Board in its relation to the Secondary Schools of Wales. The attitude of the private schools may be explained by the fact that their pupils are largely the sons of rich parents and less prone to exertion, and that outside pressure is therefore welcomed as an ally.

'At a juncture when new Universities and new Secondary Schools are being called into existence in England no feature of American education seems to offer more helpful suggestions than the accrediting system of the Middle West.'

The following statement, taken from the same source, is by Professor Gregory Foster :—

'It is a fundamental principle in American Universities that the man who is fit to teach is also to be trusted to examine his own students. The external examiner and the external examination system is practically unknown in the United States. The teachers are free, and being free they are enabled to give to their courses a breadth and depth that would be impossible were they hampered by the knowledge that their students were to be tested by examiners who knew little or nothing of them.

'The tests and examinations for undergraduate students leading to the bachelors' degrees are conducted almost entirely by the individual teachers, and with the most satisfactory results. There may be abuses from time to time by individual teachers, but, as far as I was able to discover, the evils resulting from such occasional abuses are less great and certainly less widespread than the evils of the examination systems of the British Universities. In the Universities of the States there seemed to be an atmosphere of quiet study and scholarly work which is apparently continuous throughout the session, and remains undisturbed by feverish bursts of cramming that characterise British colleges and Universities.

'The American system requires elaborate daily care and guiding, watching, and recording of students' progress, but that care probably does not involve a greater expenditure of energy than the organisation of the unwieldy examination system of this country. Moreover, as it is spread over a large period it cannot involve the terrible weariness that is brought about by the British system.

'From the point of view of the student, I have no hesitation in saying that the result is far better. When the American scheme is well carried out it ensures continuous and steady work. It makes "slacking" impossible, and thus prevents waste of time during some of the most critical and valuable years of a young man's life.

'The influence on the teacher is no less salutary ; the American teacher thinks of his functions as a teacher and director of studies, while the British teacher is driven by force of circumstances to conceive and direct

his work entirely in terms of examination. As long as examinations control the teaching, whether in Universities or schools in this country, so long will the teaching continue to be academic in the worst sense of the word, cribbed, cabined, and confined.

'From what I saw in America I am convinced that in the free system of teaching that exists there, even the week-kneed teacher gives stronger guidance to his pupils and produces better educational results than we do. The reason of this is obvious when we consider that in the American system the teacher is judged by the standard that he makes for himself, while with us the teacher has a standard imposed upon him by the examining body round the corner, which is almost inevitably a standard that tests whether the pupils have obtained the information to be found in certain prescribed books. For the English teacher with a prescribed amount of work to be got through in a certain time, whether such work is suited to the ability of the class or to the teacher's powers, life is a continual rush. There is no time to deal in educational fashion with the mistakes of his pupils ; they are simply told that they are wrong and one of the others is set to put them right. Whereas for the American teacher life is in comparison a leisurely one. He makes as much if not more educational value out of the blunders of his weaker pupils as out of the correct answers of the stronger ones. He cares for the development of his class as a whole, and not mainly for that of those who will do him the most credit in answering the questions of an outsider.

'The degree to which examination by external bodies or examiners are regarded as baneful both to the pupil and for educational organisation is shown by the fact that they only exist for the purposes of professional qualifications in certain States and for the purposes of admission to Universities and colleges in certain other States. Even where they exist the evils that have been so strongly felt in this country have been largely guarded against. Thus an examination board has been formed by the Association of Colleges and Preparatory (*i.e.* preparatory for the colleges and Universities) Schools of the Middle States and Maryland for the purpose of instituting a common standard for admission to the colleges belonging to the association and of holding one examination for the purpose of that admission. Great care has been taken that the examiners in each case shall be experienced teachers, and inasmuch as the examination for admission to college is the test of the work done in the preparatory school, a large proportion of the examiners consists of masters who have been teaching in one or other such school.

'The papers set by this examination board seem to me on the whole admirable and well calculated to stimulate good teaching. While this has been done in the East in order to obviate the occurrence of many examinations, and in order to remove the difficulties that beset the old-fashioned Matriculation Examination which was mainly set by college or University professors in the Middle West, an even more significant system known as the accrediting system has been originated, and this system is rapidly spreading into the East. The accrediting system seems to have originated at the State University of Michigan, and to be largely due to the wisdom and foresight of President Angel. The old system of Matriculation Examination was not only found to be an unsatisfactory test of the pupils, but was found to be an actual bar to any satisfactory relations between the Universities and colleges and the schools. The University of Michigan determined, therefore, to institute a list of high

schools, to be known as "accredited schools," from which schools pupils who presented certificates of having satisfactorily passed the full four years' high school course would be received without examination into the University. One of the University professors of education has for his main function the visitation of schools with a view of testing their fitness to be placed on the accredited list. He is from time to time assisted by his professorial colleagues, who inspect the schools from the point of view of their special subjects. Schools that are found satisfactory in all respects are placed on the accredited list; others have their deficiencies pointed out to them, and are told that when these are remedied they, too, will be put on the list.

'When a school has been placed on the list it is still subject to inspection. It receives a report from the University upon each student that it sends thereto at the end of his first session or first semester, as the case may be. The University reserves to itself the right to refuse a student who is found to be insufficiently prepared to go on with his studies, and also the right to withdraw from the accredited list the name of any school that is proved by the pupils that it sends up to have an unsatisfactory standard. The result of this is that in the States where it has been adopted the whole educational system has been unified and strengthened. The University is looked up to as a counsellor and friend of the schools; the University teachers learn much by continued intercourse with their scholastic colleagues and *vice versâ.*

'In this way the barriers that exist in many countries between the various grades and teachers are rapidly being removed, and, what is even more important, the teaching of all classes of teachers is thereby made more direct, more stimulating and attractive, to the students. Here and there I met teachers who disliked the accrediting system and preferred the old examination system, but the vast majority were strongly in favour of the former. They pointed out that no system that had been, or as far as they could see, could ever be devised, would ensure that all the students entering a given class in a given year at the University would all approximately start with the same amount of training and learning.

'At the same time the accrediting system, as against the older system, leaves the teacher and the taught free, and thereby stimulates better training. So strong is the feeling in favour of this system in the Middle West that even entrance scholarships to the colleges and Universities are awarded by it. The entrance scholarships are allotted among the accredited schools, each school taking its turn, and receiving as nearly as possible the number of scholarships proportioned to its own number of students, and to the number who proceed from the school to the University.

'The evidence given by Professor Harper in favour of the system was very striking. He said that when he left Yale to go to Chicago he was opposed to the accrediting system, but that experience in the Middle West had led him to change his opinion, and that now he is a firm believer in it. In order further to extend the system, and to prevent needless repetition of work, the State Universities of the Middle West propose to draw up a list of the schools that can be accredited by all of them. The standard for this joint list is to be somewhat higher than the standard adopted by the Universities singly for their several lists. As I have already said, the system is gaining favour in the East, and with the exception of Harvard, Yale, Princeton, and Columbia Universities it has,

I understand, been adopted more or less by all the Eastern colleges and Universities. This is a signal triumph and evidence of the value of a course of study of fixed duration, carefully graded and carefully watched at every turn, over the sort of racehorse method that turns our schools into training grounds for the examination race that occupies a few days at the end of a boy's school career, and upon which his future is made to depend to an alarming extent. This system is perhaps one of the most noteworthy contributions of America to educational progress. Its adoption indicates that America at all events realises that education is a slow process which must be spread over certain fixed periods of time, that there are no short cuts, that even though the boy may have acquired the requisite information to answer the questions of an outside examiner, it does not follow that he has been satisfactorily educated to the standard that that examination is supposed to represent. It is only another instance of the responsibility and consequently of the dignity that is cast upon the teacher. To dignify the teaching profession is a certain way of making it strong. To deprive it of dignity by showing lack of trust in it by all sorts of rules and regulations and by outside restrictions and examinations is a sure way to degrade it.'

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. F. W. RUDLER (*Secretary*), Sir JOHN EVANS, Rev. J. O. BEVAN, Dr. HORACE T. BROWN, Dr. VAUGHAN CORNISH, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Professor R. MELDOLA, Dr. H. R. MILL, Mr. C. H. READ, Rev. T. R. R. STEBBING, Professor W. W. WATTS, *and the* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Corresponding Societies Committee have to report that during the past year the Quekett Microscopical Club and the Southport Literary and Philosophical Society have been added to the list of Societies in correspondence with the British Association.

The Committee have had under consideration the suggestions which were brought before the Conference of Delegates at Southport by Mr. William Cole, of the Essex Field Club, with regard to Exploration and Registration Work for certain local Societies. With Mr. Cole's general objects the Committee cordially sympathise, and they have recommended that local Societies should make it a part of their systematic work to enter upon the 6-inch Ordnance maps of their respective districts any natural features and archæological remains which are not indicated thereon. With regard, however, to the suggestion that the County Councils should be asked to allocate an annual sum to the central scientific Society of each county for the purpose of carrying out the work of local exploration and registration, the Committee have felt that it is not within their power to take any action.

The Committee have also considered a suggestion from the Rev. E. P. Knubley with reference to the assistance which local Societies might render to teachers anxious to introduce Nature-Study into their schools. In accordance with this suggestion, the Committee strongly recommend that the Corresponding Societies should assist, by scientific advice and otherwise, those teachers in elementary and secondary schools who are taking

up such work. It is understood that a Committee of the Section of Educational Science will submit a Report on the subject of Nature-Study at the Cambridge Meeting; and in view of such a Report the Committee consider that, at present, it would be premature to discuss details, and consequently content themselves with commending the subject as one well worthy of the attention of the Corresponding Societies. It is satisfactory to learn that certain Societies have already undertaken such work. Thus, the Halifax Scientific Society reports that it has sought to promote Nature-Study by giving lectures to children and scientific aid to teachers; whilst the Croydon Natural History and Scientific Society reports that it is furnishing loan-collections of natural-history objects to schools, and has further assisted educational work by means of addresses.

The usual appeal has been made to the various Corresponding Societies for suggestions as to subjects suitable for discussion at the forthcoming Conference of Delegates. In response to this request the Hertfordshire Natural History Society has suggested that it would be desirable to discuss the question of the conformity of the publications of the Societies with certain bibliographical requirements. The Committee consider that this is a subject of much practical utility, and Mr. John Hopkinson, a member of the Committee and editor of the 'Transactions' of the Hertfordshire Society, has undertaken to bring the subject forward at Cambridge.

Dr. Tempest Anderson, who will act as Vice-Chairman of the Conference of Delegates, and the Rev. W. Johnson, representing the Yorkshire Philosophical Society, have suggested the importance of discussing the best method of utilising Local Museums in connection with Elementary and other Public Schools. The Committee agree that this is an important subject worthy of the attention of the Corresponding Societies, and Mr. Johnson has consented to open a discussion on the subject by reading a paper at the Cambridge Conference.

The Committee have heard with satisfaction that several Societies, acting on a suggestion made last year, have appointed Standing British Association Committees, but it is perhaps as yet too early to learn the result of such action. Only twelve of the affiliated Societies, in returning the schedules which are sent out annually, have reported that they have been able to do any original work during the past year. It appears that most of the work undertaken has been of a botanical character, relating principally to local botanical surveys.

Without suggesting further subjects for research, the Committee desire to urge upon the representatives of the various local Societies the desirability of taking up some of the subjects already set forth in former Annual Reports of the Committee. Moreover, it is desirable that the Societies should endeavour, as far as possible, to assist the work of the various Committees of the British Association which are appointed in connection with its several Sections. Some of these Committees, it is true, have already been indebted for such aid, but it is believed that there are many other Committees which might receive substantial help if the local Societies would undertake the work with enthusiasm.

Report of the Conferences of Delegates of Corresponding Societies held at Cambridge, August 18 *and* 23, 1904.

Chairman	.	Principal E. H. Griffiths, M.A., D.Sc., F.R.S.
Vice-Chairman	.	Tempest Anderson, M.D., B.Sc.
Secretary	.	F. W. Rudler, I.S.O.

The Conferences were held on Thursday, August 18, and Tuesday, August 23, at 3 o'clock P.M., in the Lecture Room, Gonville and Caius College.

The following Corresponding Societies nominated Delegates to represent them at the Conferences. The attendance of the Delegates is indicated in the list by the figures 1 and 2 placed in the margin opposite to the name of each Society, and referring respectively to the first and second meetings. Where no figure is shown it will be understood that the Delegate did not attend.[1]

List of Societies sending Delegates.

1	2	Andersonian Naturalists' Society	Mrs. Ewing.
1	2	Ashmolean Natural History Society of Oxfordshire.	G. Claridge Druce, M.A.
		Bath Natural History and Antiquarian Field Club.	Rev. C. W. Shickle, M.A., F.S.A.
1	2	Belfast Naturalists' Field Club	W. J. Fennell.
		Belfast Natural History and Philosophical Society.	Professor Gregg Wilson, D.Sc.
1	2	Berwickshire Naturalists' Club	G. P. Hughes, F.R.G.S.
1		Birmingham and Midland Institute Scientific Society.	C. J. Watson.
1		Birmingham Natural History and Philosophical Society.	Herbert Stone, F.L.S.
	2	Bristol Naturalists' Society	J. D. Fry.
	2	Buchan Field Club	J. F. Tocher, F.I.C.
1		Caradoc and Severn Valley Field Club	Professor W. W. Watts, F.R.S.
1	2	Cardiff Naturalists' Society	A. H. Trow.
1		Chester Society of Natural Science, Literature, and Art.	A. O. Walker, F.L.S.
1	2	Croydon Natural History and Scientific Society.	W. F. Stanley, F.G.S.
1	2	Dorset Natural History and Antiquarian Field Club.	Clement Reid, F.R.S.
		Dublin Naturalists' Field Club	Dr. A. C. Haddon, F.R.S.
1	2	East Kent Scientific and Natural History Society.	A. S. Reid, M.A.
	2	Edinburgh Geological Society	David Tait.
1	2	Essex Field Club	F. W. Rudler, F.G.S.
1		Glasgow Royal Philosophical Society	Professor Archibald Barr, D.Sc.
1	2	Glasgow Natural History Society	Peter Ewing, F.L.S.
1		Halifax Scientific Society	W. Ackroyd, F.I.C.
1	2	Hampshire Field Club and Archæological Society.	T. W. Shore, F.G.S.

[1] The attendances are taken from the Attendance-book, which each Delegate is expected to sign on entering the Conference.

1	2	Haslemere Microscope and Natural History Society.	Rev. G. B. Stallworthy.
1		Hertfordshire Natural History Society	Percy Manning, M.A., F.S.A.
	2	Holmesdale Natural History Club .	Miss Ethel Sargant.
		Hull Geological Society	J. W. Stather, F.G.S.
		Hull Scientific and Field Naturalists' Club.	T. Sheppard, F.G.S.
1	2	Institution of Mining Engineers .	Rev. G. M. Capell.
		Isle of Man Natural History and Antiquarian Society.	Professor W. A. Herdman, F.R.S.
		Leeds Geological Association . .	Professor P. F. Kendall, F.G.S.
		Leeds Naturalists' Club and Scientific Association.	H. C. Marsh.
1		Liverpool Geographical Society . .	Captain Phillips, R.N.
	2	Liverpool Geological Society . .	Joseph Lomas, F.G.S.
		Manchester Geological and Mining Society.	Professor W. Boyd Dawkins, F.R.S.
	2	Manchester Geographical Society .	H. Yule Oldham, M.A.
1	2	Manchester Microscopical Society .	F. W. Hembry, F.R.M.S.
		Manchester Statistical Society . .	Professor S. J. Chapman, M.A.
		Marlborough College Natural History Society.	E. Meyrick, F.R.S.
1	2	Midland Counties Institution of Engineers.	Rev. G. M. Capell.
1	2	Midland Institute of Mining, Civil, and Mechanical Engineers.	Rev. G. M. Capell.
1		Norfolk and Norwich Naturalists' Society.	Walter Garstang, M.A.
		Northamptonshire Natural History Society and Field Club.	Beeby Thompson, F.G.S.
1	2	North of England Institute of Mining and Mechanical Engineers.	Rev. G. M. Capell.
		North Staffordshire Field Club . .	W. D. Spanton, F.R.C.S.
		Nottingham Naturalists' Society .	Professor J. W. Carr, M.A., F.L.S.
		Paisley Philosophical Institution .	John Woodrow.
1	2	Perthshire Society of Natural Science	A. S. Reid, M.A.
1	2	Quekett Microscopical Club, London .	John Hopkinson, F.L.S.
1	2	Rochdale Literary and Scientific Society.	J. R. Ashworth, D.Sc.
1	2	Somersetshire Archæological and Natural History Society.	F. J. Clark, F.L.S.
1	2	South-Eastern Union of Scientific Societies.	Rev. R. A. Bullen, B.A., F.L.S.
		Tyneside Geographical Society . .	Herbert Shaw, F.R.G.S.
1		Warwickshire Naturalists' and Archæologists' Field Club.	William Andrews, F.G.S.
1	2	Woolhope Naturalists' Field Club .	Rev. J. O. Bevan, M.A., F.S.A.
1		Yorkshire Geological and Polytechnic Society.	Rev. W. Johnson, B.Sc.
	2	Yorkshire Naturalists' Union . .	W. West, F.L.S.
1		Yorkshire Philosophical Society .	Dr. Tempest Anderson, B.Sc.

First Conference, September 8.

This Conference was presided over by Principal E. H. Griffiths, F.R.S. The Corresponding Societies Committee was represented by Mr. Whitaker, F.R.S., the Rev. J. O. Bevan, the Rev. T. R. R. Stebbing, F.R.S., Professor W. W. Watts, F.R.S., Mr. J. Hopkinson, and Mr. Rudler.

The Chairman, as an old Cambridge man, offered a cordial welcome to the Delegates, and acknowledged the courtesy of the Master and Fellows

of Gonville and Caius College in having placed some extremely convenient rooms at the disposal of the Delegates.

The Secretary then read the Report of the Corresponding Societies Committee, which was adopted.

The Chairman, before proceeding to deliver his Address, remarked that his object on that occasion was more to promote discussion and arouse attention on certain matters than to obtain any very definite expression of opinion. He proposed, after having read his Address, that there should be a discussion on the points raised therein, but perhaps any definite conclusion had better be reserved until the second meeting.

Principal Griffiths then read the following Address :—

I assume that the chief object of these Conferences is the quickening of general interest in the study of Natural Science and in the work of the British Association. Our duties are not those of a Section, but rather those of the husbandman who prepares the ground in the hope and belief that the Sections may hereafter reap the harvest; or, to vary the image, we are here to study the machinery rather than its products.

A study of the Reports of the Conferences of the Delegates of Corresponding Societies from the time that such Conferences were officially instituted in 1884 leaves the impression, at all events upon my mind, that the results have scarcely been commensurate with the expectations of those who instituted this body, or with the possibilities presented by the situation.

It is stated—I believe on good authority—that there are in this kingdom something like 500 Scientific Societies with a total membership approaching 100,000, and that at the present time both the number of Societies and of the members thereof is steadily increasing. I think we may say without hesitation that the general interest of the British public in science is greater now than at any previous time in our history. Nevertheless the number of Societies affiliated to the British Association is but a small proportion of the total, and I am afraid that of many of those it may be said that the connection is nominal rather than real.

Sir Norman Lockyer, in his Address at Southport, spoke as follows :—

'We not only, then, have a scientific Parliament competent to deal with all matters, including those of national importance, relating to science, but machinery for influencing all new councils and committees dealing with local matters, the functions of which are daily becoming more important.

'The machinery might consist of our Corresponding Societies. We already have affiliated to us seventy Societies with a membership of 25,000. Were this number increased so as to include every Scientific Society in the Empire, metropolitan and provincial, we might eventually hope for a membership of half a million.'

This of course is an impressive statement, but the weight thereof depends very greatly on the real meaning of the expression 'affiliated to us.'

Is this affiliation a real thing? Let us see what it means in practice. A Society consisting, perhaps, like the one I represent, of between 400 and 500 members, nominates one Delegate. Of the Delegates thus appointed it would appear from our past records that not more than some fifty or sixty per cent. present themselves at our meetings; and, although there is evidence that the action of some few Societies has been directly influenced by our proceedings, I confess that the results can hardly be

considered satisfactory when we contemplate the elaborate machinery by which they have been obtained and the labours of those who have kept the machinery in action. I trust the Delegates will not suppose that I am endeavouring to belittle the importance of these Conferences. I believe that, rightly directed, we have here a body which may become an immense power for good, and that this child, which I am afraid is regarded by some as the Cinderella of the family, may grow to be one of the greatest of the daughters of the Association.

Whatever may be our opinion on the fiscal question, or the extent to which we are suffering from the competition of other nations, men of all parties will, I trust, be at one in the belief that, whatever remedies may be suggested, there is urgent need of better education in science, as well as of more scientific education. Not only is the comparative pace of our competitors increasing, but unfortunately they have, as pointed out by Sir N. Lockyer, gained upon us at the start. Our immediate duty is to place the needs of higher scientific education before the people of this kingdom. Once convince 'the man in the street' that his business prosperity, nay, his very wages, are adversely affected by our inadequate system of higher education, and our difficulties will speedily vanish !

Consider a somewhat parallel case. You may remember how some fifteen to twenty-five years ago a number of able and enthusiastic men succeeded in convincing the British voter that his safety and prosperity depended upon an efficient Navy, and how, since the time that this conviction was brought home to the minds of our countrymen, no difficulty has been experienced in obtaining the funds necessary to create a Navy commensurate with our needs.

Let us profit by this example. Our rulers are, I believe, already convinced of the advisability of rendering increased assistance to the cause of scientific investigation, but they cannot loosen the Imperial purse-strings until they know that the country is prepared to acquiesce in a liberal policy.

Our task is that of 'spade work,' and should be even a less heavy one than that undertaken by our naval reformers, for we can show that, once established, a satisfactory system of high scientific education, so far from being a cause of continual outlay, will add to the wealth and prosperity of our country.

But it may be asked, 'What has all this to do with the constitution of this body ?' I think the connection is evident. If we could supply the links which would bind together all the Scientific Societies of this kingdom, so that in matters of national importance they would move as a united body, it would be difficult to overestimate the influence which could be thus exerted, for it is certain that amongst the members of these local Societies are included many of the most intelligent and influential men in their respective districts. At present, however, apart from their interest in natural science, these local Societies have little in common. We may picture them as a scattered heap of iron filings, and we want the British Association to be the magnet which, placed in their midst, will transform the confused assemblage into a field of symmetry and beauty.

The work of local Societies is of two kinds : one may be termed educational, the other technical. In the latter I include actual observational and investigational work. I confess that, at the present time, I regard the former as the more important branch. The work is educational, not only in arousing intelligent interest in the facts of natural science and

quickening in the individual the power of observation, but also in promoting the missionary spirit which will enable the members to excite the interest and sympathy of their neighbours. It is possible that our present constitution does not attach sufficient importance to this *educational* part of the work. I refer especially to Regulation I., which confines the right of representation at this Conference to those Societies which publish proceedings. Now it is very doubtful if publication *is* the best test of merit. My own impression is that we have '*too much cry*' *for the amount of* '*wool*,' and if we exclude from our deliberations all those Societies whose circumstances or inclinations have caused them to refrain from adding to the mass of literature under which there is danger of our being smothered, it is possible that we are excluding the very bodies whose sympathy and interest we should most wish to encourage. If we are to lay down some criterion, I would suggest that of membership rather than that of quantity of print.

It is true that as the Delegates become *ex-officio* members of the General Committee of the Association some guarantee ought to be given that those who receive this privilege have some real knowledge of, and interest in, natural science. This difficulty might be met by the establishment of two classes—namely, *affiliated* and *associated* Societies. Delegates from *affiliated* Societies (those which undertake local investigations and publish the results) might continue to receive, as at present, the privilege of membership of the General Committee; whereas Delegates from the *associated* Societies might be invited to take part in the deliberations of these Conferences and to receive copies of the reports, &c., without becoming members of the General Committee. Any local Society which has existed for a period of, say, three years, and numbers not fewer than fifty members, might well receive the right of appointing a representative. Surely we desire to throw our doors as wide open as possible; surely we wish to give every encouragement to all scientific Societies, but more especially to those working under difficulties, to strengthen the hands of their promoters and to ask their aid and assistance in our deliberations. Moreover, it is precisely those Societies with narrow means, and whose members are possibly drawn from the working classes, that can be of the greatest use to us. They are missionaries situated where we most want them, and preaching to the unconverted. This yearly meeting of single Delegates from a few of the leading Societies, although an admirable nucleus, is not sufficient to produce crystallisation of the scientific interests in solution in the population of this kingdom. We want more frequent means of intercommunication, more power of directing individual movements towards one common object. I suggest that all associated and affiliated Societies should be asked to make a small contribution (to some extent proportional to their numbers) in order to defray the expenses of a Journal of Corresponding Societies, which would be published at stated intervals. An annual contribution at the rate of, say, 5*s*. per fifty members would, with our present constituency, produce a sum exceeding 100*l*. per annum, and if the suggestion as to the addition of associated Societies be accepted, I believe this sum would soon be more than doubled. The Council of the British Association might well be asked to contribute an annual grant during, say, the first three years; after which interval I believe the scheme might become self-supporting. Such a journal should start on very unambitious lines: it should contain a list of the meetings which have taken place since the preceding week, the titles (*merely*) of

any papers which had been read, and official notices from any Societies which wished to call attention to work requiring co-operation, or to points upon which information was desired. The great use of such a journal would be that, at any time, it would be possible to unite all the connected Societies in common action for the attainment of some purpose of national or scientific importance; and if this journal was edited under the auspices of the British Association, the connection with the Central Body would be brought home in a very real manner to the members of this scattered constituency. Few Societies would grudge this small contribution of scarcely more than one penny per annum per member. I am aware that many objections could be urged against such a scheme; but I do not think that the difficulties are insurmountable, and, once surmounted, a great step would have been taken towards the utilisation of that general interest in natural science of which the best evidence is to be found in the growth, the numbers, the variety, and the labours of the local Societies of this kingdom.

I trust it will be understood that I make these suggestions with great diffidence. I have taken no part in the work of these Conferences in the past, and it was therefore with considerable hesitation that I accepted the honour of nomination as your Chairman to-day.

The circumstances under which I have been placed during the past two years, however, have strongly impressed upon me the possibilities placed at our disposal by the existence of local Societies. I am living in the midst of a great working-class population, and have been brought in contact with the workers in the coal mines of Glamorgan and Monmouth. I am also serving on educational and other bodies in which these workers are largely represented. At first it appeared to me that any demands for assistance for higher scientific education or research were regarded with indifference; but I have found that when the facts of the situation were placed before the men or their representatives, when it was pointed out to them how greatly their employment and their interests were dependent on the results obtained by scientific investigations, their attitude of indifference—if not of suspicion—was replaced by one of sympathy and good will. Our local Societies have it in their power to bring such facts home to the people of this country, and, great as are the services which the British Association has rendered in the past, I believe if it can accomplish the task of uniting the activities of our local Societies in one common effort, it will not be reckoned amongst the least of the achievements of the Association. Having tendered this apology for my audacity, I now venture to ask the Delegates to give their consideration to the following proposals, it being understood that, even if the principles therein conveyed are approved of, these proposals will require redrafting, and that consequent ones connected with matters of detail will require careful consideration:—

(1) That any Society which undertakes local scientific investigation and publishes the results may become a Society affiliated to the British Association.

(2) That the Delegates of such Societies shall be members of the General Committee.

(3) That any Society formed for the purpose of encouraging the study of natural knowledge which has existed for three years and numbers not fewer than fifty members may become a Society associated with the British Association.

(4) That all associated Societies shall have the right to appoint a Delegate to attend the Annual Conference, and that such Delegates shall have all the rights of those appointed by the affiliated Societies, except that of membership of the General Committee.

(5) That all affiliated or associated Societies shall contribute annually the sum of at least 5*s.* for each fifty members, and that the funds thus obtained be utilised for the purposes of a 'Journal of Corresponding Societies.'

(6) [In case proposition (5) is approved :]

That the Council of the British Association be requested to make an annual grant towards the expenses of such a Journal on the understanding that such grants shall cease if the Journal become self-supporting.

Mr. W. Whitaker, in opening the discussion, remarked that he had listened to this Address with very great pleasure, and was glad to find that the Chairman had been thinking on almost the same lines as he had himself for a few weeks. The speaker wished to bring before the meeting the terms on which Societies are affiliated, because it seemed to him that the time had come when it might be well to reconsider those terms and perhaps revise them. The existing rule is that they should take all Societies who publish original work. That rule is fixed by the General Committee. On the face of it, it was a very good rule indeed, and it had worked very well so far ; but the speaker was faced a few weeks ago with this difficulty. Visiting a Society in a fairly out-of-the-way country place he found it did not publish anything but the bare Annual Report. Yet it had a splendid museum. This was kept in very good order, with the specimens properly labelled. Why did not that Society publish ? One reason was that it had spent all its money on the museum. Did they not think it had done quite as well in keeping up that museum as if it had published ? It seemed to him that work of that sort ought to be encouraged. He suggested that, after discussion here, the Delegates should request the British Association Committee of the Corresponding Societies to consider the terms on which Societies are affiliated. He was sure those members of the Committee who were present would be glad to act on the lines which the Delegates desired. Whether they adopted or not all the propositions the Chairman had brought forward was another question altogether. The speaker differed very much from him in details, but on the general principle he entirely agreed with him, and hoped something would be done to enforce that general principle and widen their bounds by letting them take in many Societies who really do very good work, although they publish but little.

Sir Norman Lockyer said he had listened with great pleasure to the Chairman's remarks, and, like the previous speaker, he felt that his pleasure was all the greater because they corresponded closely with some of his own views. Last year he attended the Conference at Southport chiefly to learn how the suggestion in his Presidential Address as to the formation of a great scientific organisation would be received by the Delegates. He might now explain that a British Science Guild was being started, quite independently of the British Association ; and it seemed to him that the Guild could work absolutely shoulder to shoulder with the Societies in the extension of their interests. He was rejoiced to hear the proposal that there should be more frequent communication between the representatives of the Societies than is afforded by the

Annual Meeting of the Delegates. He could quite understand that there might be numerous questions cropping up in the course of the year which it would be very desirable to discuss in Conference. He felt certain that many of the Societies would see that, in addition to the work which they were now doing, it was necessary in the interests of science to influence the man who has to vote, not only in the County Councils, but in the House of Commons.

Mr. P. Ewing (Glasgow) spoke in support of the suggestions made by the Chairman.

The Rev. G. B. Stallworthy (Haslemere) said he had very strong faith in the value of the local Societies, and also in the connection between the local Societies and the British Association. He felt very grateful for the pressure put upon the Societies by headquarters to make them do something. This year they had succeeded at Haslemere in publishing two papers, but they were rather dry: one was a catalogue of fungi. Only about five per cent. of the members purchase such things. For all that, it had had a very healthy influence upon a small circle of the members. A practical suggestion the speaker was about to make was this, that possibly a Central Committee might consider whether it were possible to appoint a dozen responsible gentlemen who would visit these local Societies. A few of the Delegates attend the British Association, and they are able to interest just a few round about them; but the interest would be very greatly increased and deepened if a gentleman representing the British Association would come to the local Society with a message from headquarters. That message would reach the great majority of those who attend meetings. He did not regard it as a very practical test as to whether they had a museum or not. Some Societies do not own a museum, because there is already a museum existing in their locality. He thought that if admission to the Association depended upon the recommendation of one of these officials, who would come down, say, once annually or two years in succession, and report upon the nature of the Society, the kind of work done, and the healthiness of it, such a report by a responsible inspector appointed by the Council might be an important factor in determining the question of admission of the Society.

Dr. G. Abbott (Tunbridge Wells) wished to support the suggestion just put forward. To his mind the solution of many of the difficulties that were felt would depend on the formation of unions of the Societies in different districts of the country. If there were a union of the Societies in four or five counties, very many more of those Societies would send Delegates to these meetings. One of the chief advantages of the union with which he was connected, the South-Eastern Union, was that it had brought the Societies together. They had got to know men who were giving good lectures, and who were prepared to repeat them. In that way many friendships had been formed and many Societies had been strengthened.

The Rev. T. R. R. Stebbing called attention to one departure from precedent which he thought was of the very highest value. Last year the Delegates were honoured by the attendance at this Conference of the President of the Association. This year again they had the presence of the outgoing President. What he wished to insist upon was this, that they should if possible persuade all Presidents and outgoing Presidents to do as Sir Norman Lockyer had done. He hoped that next year Mr. Balfour would take care to honour the Congress with his company.

He was sure that would give a very great access of dignity to this Conference of Delegates. In the 'Daily Journal' they had a long list of the Sectional Committees, but no list of the Delegates of the Corresponding Societies.[1] One other point. He was very gratified indeed to hear the Chairman's suggestion to recognise the association of Societies independently of publication. If communications were of importance they should be published by some great Central Society, and if unimportant they were perhaps better left unpublished.

Mr. A. O. Walker, referring to the suggested payment of 5*s.* per fifty members, said he represented a Society which had a thousand members, and accordingly on these terms their subscription would be 5*l.* a year. He was sure they could never afford it.

Mr. Theodore Reunert (Johannesburg) stated that he had the honour to be President of the South African Association for the Advancement of Science, which would act as an agency of the British Association on the occasion of their visit to South Africa in 1905. He then explained briefly what is the present state of things in South Africa scientifically. The South African Association was formed three years ago in Cape Town, during the war, with Sir David Gill as the first President; and it now has members all over South Africa, from Cape Town to the Zambesi, who number something like two thousand. Perhaps it would interest the meeting to hear that one of the most gratifying features of this new South African Association was the hearty and sympathetic support which it had received from the various Governments of South Africa. On the occasion of its first annual meeting in Cape Town the Government of Cape Colony voted something like 400*l.* to defray the whole cost of publishing their first year's proceedings. The Government of the Transvaal Colony, on the occasion of their second annual meeting, voted a similar sum for the publication of that year's proceedings, and the various Governments among them have voted 6,000*l.* towards assisting in the expense of the British Association's visit in 1905.

Mr. H. Reid (South African Association for the Advancement of Science) thought that a great deal of the lack of general interest in science may be due to want of help and encouragement from the central bodies in dealing with local Societies.

The discussion of the Chairman's Address was then adjourned until the next meeting.

In answer to a question by Captain Dubois Phillips, R.N., the Secretary said that the question of the reduction of railway rates for members of scientific societies had been under the discussion of the Committee, but no definite result had yet been attained. It was a matter involving considerable difficulty.

The Chairman said he thought that naturalists should be treated as generously as anglers. He thought the most effective way of taking action would be to ask the Committee to draw up a statement and forward it to all the affiliated Societies with a request that they would sign it, so that there would be united representation from all parts of the country. He believed that if the Presidents and Secretaries signed a

[1] The names of the Delegates are printed in a conspicuous position in the List of Members, and before the conclusion of the Cambridge Meeting a List of Delegates appeared also in the 'Daily Journal' in response to the appeal above recorded.

statement and sent it to the managers of the railways, they would probably effect their purpose. He suggested that the Delegates should ask the Committee if they could see their way to discuss this matter, and, if possible, draw up a memorial.

Dr. Abbott proposed that the matter should be referred to the Corresponding Societies Committee to consider and take action. This was seconded and agreed to.

It was resolved that an application should be made to the Committee of Recommendations, asking for the reappointment of the Corresponding Societies Committee, with a grant of 25*l.*

The Rev. W. Johnson, B.A., B.Sc. (Yorkshire Philosophical Society), introduced the following subject :—

The Utilisation of Local Museums, with Special Reference to Schools.

The selection of this subject for discussion is probably due to certain remarks made at the Southport meeting last year, when it was hinted that the local museum was often the dumping ground of curious finds for which room could not be provided by the discoverers, instead of being the centre of living interest and new growth. I presume the Association regards the local Societies *as feeders*, and therefore puts on us the duty of laying the foundation of the scientific habit, and of providing the means of satisfying the longing for more insight into nature. It will be at once apparent that the subject has certain limitations. We must confine ourselves almost entirely to the natural-history side of science study, partly because the general interest of workers lies there, and partly because the local museums lack storage-room for specimens suitable for illustration of the other branches.

In discussing the question of 'The Utilisation of Local Museums,' in connection with the science work of our school, I lay down the following propositions : (1) a great amount of material lies *buried* in local museums ; (2) it needs *proper description* and *exhibition* to make it available for the use of young students ; (3) it is very desirable that *local* natural history, rather than general science, should be *illustrated and studied* in this connection.

Collecting, merely for possession of a collection, has been sufficiently disparaged without our adding another word of condemnation. When a young student approaches a specimen, a mere label is often inadequate to attract and inform him. Therefore it is necessary that a more or less detailed description, with drawings of separate parts, should be placed with the specimens *side by side* in order that there may be no mistake. The method adopted in the Natural History Museum, Cromwell Road, London, is, in my opinion, most effective to this end. There the admirable handbooks, issued in each section are taken paragraph by paragraph, and each statement made in the whole description is represented by a real object by its side, so marked by coloured papers, arrows, and guiding lines that a student who works through the cases in succession follows a natural sequence of treatment under scientific guidance. I have often thought that local museums have failed in developing the scientific habit because they have given undue prominence to what is *special* or *rare*. Now a beginner wants help in identifying what is *common* or elementary, for when, on going out on his field-days, he discovers none of the rarities dis-

played in his museum, he is too apt to think that none of his work is worth the trouble, and may be checked at the start in the proper classification of his work.

Having made it my aim to visit local museums wherever possible, I am able to speak at first hand of the hopeless confusion which misleads and repels, in spite of the abundance of most valuable material. Some Yorkshire museums need immediate reclassification and arrangement.

I would propose that each town should have a strictly limited collection of the natural objects which are commonly found in that area ; that the flora and fauna should be separate ; that the district in which each is to be found should be indicated ; that, in the case of the flora, the months during which the plants may be found should be added, and that detailed descriptions by competent persons should be attached ; that in every museum there should be a large geological map of the area, with suitable vertical sections, showing the connection between the underground conditions and the variety of life on the surface.

I should like to see in each museum a collection of the natural orders of plants, pressed specimens obtained locally and easily accessible to individual students, in order that the flora of the district might be within the knowledge of each boy and girl educated in the area. So, too, with the rocks. There should be a complete series of hand specimens of rocks illustrating the succession of strata in the neighbourhood, and, if the rocks are fossiliferous, or capable of economic use, then the fossils should be associated with the rocks and the economic products exhibited and explained. Each section should be kept in its own room for separate use.

This small teaching collection need interfere in no respect at all with the general purpose of the museum as the receptacle of objects of interest of all kinds ; but would ensure, to all who wished it, a proper start on right lines, and would engender in them a keen desire to proceed to a wider knowledge of that branch which interests them.

Now comes the question whether we should take the specimens to the classes in schools, or take the classes to the specimens in the museums. Personally I am in favour of the latter. I have watched with interest the growth of the latter plan in Leeds, where excellent results appear to be accruing from the admirable lectures and demonstrations of the Curator of the Leeds Museum, Mr. Crowther. But, apart from the evident success of this scheme, it would teach the young student to regard the museum as the centre of his work, and having been taken there by his teachers for the work of a course, he would soon be found there on his own account, searching for himself answers to questions which have arisen from his own work ; and every museum would become the training ground of a new set of investigators. It may be asked, when can time be found for all this ? And that really is a serious question. Yet there is a good answer. During the winter holidays afternoon demonstrations could be given in every centre without dislocating any time-table ; and as there is, I believe, a strong tendency to reduce the demands of 'home lessons' a course of evening demonstrations during term could be no heavy infliction on the children, and would be welcomed alike by them and their parents.

Now, presuming we have the contents of our museums in order, so reduced in number as not to be bewildering, and so definitely described as to be intelligible, we should easily be able to get the young student to take interest in them. By taking our classes to the museum we should,

at any rate, teach him the way to the museum. It would accustom him to the idea of resorting to a definite place for the solution of his difficulties. It would make the museum the centre of distribution for much useful knowledge, whereas it is too often a swamp in which the streams of knowledge lose themselves. If we could ensure on the part of the teachers a definite acquaintance with the contents of the museums, it would be easy for them in the course of their lessons to refer their pupils to specimens which more fully illustrate the matter under discussion, and thus the grafting of one upon the other would be effected. I am not quite sure whether it would be better to depend on the curators of the museums (or of sections of the museums) for the descriptions or demonstrations, or to attempt to put this on the teachers of the schools. The advantage of the former course would be the intimate acquaintance with the subject and with the specimens of the museum ; of the latter a better acquaintance with the students and their powers, and probably a better aptitude for imparting knowledge due to professional training. If, as is, I believe, the case with the Curator of the Leeds Museum, these qualities can be found combined in the curator, I should have no hesitation about entrusting the whole of the work to him.

I imagine that one of the greatest difficulties likely to be met with in the utilisation of our museums will be that of continuity of work, for if frequent changes take place in these offices, the development of the work must suffer from want of sequence. It would probably be wiser to secure, if possible, the attention and care of the science teachers of our schools. We should thus gain the double advantage of a definite interest in a science, and a definite interest in the schools which are using the museum and the course of work. The increasing number of science teachers is a guarantee of a continuous supply of curators.

Especially do I think it advisable and desirable that a course of, say, four or five lectures should be given during the winter holidays on the elementary laws of meteorology, with an explanation of the instruments which are used for obtaining weather records, both how they are made and how they are used, together with the chief corrections which are needed to ensure an accurate result. In many museums these instruments are accessible to the public, and a knowledge of their use ought to be common property.

There appear to be, in connection with museums, few rooms which are capable of accommodating a class of students for demonstrations. This is an obvious defect, if anything more than individual work is to be attempted, and one of the first improvements to be effected by our museum trustees will be the provision of such rooms with lanterns, screens, and lecture-room appliances adequate for the proper accomplishment of this work.

I ought to say one word as to the cost of this new development. Many of the curatorships of our museums are honorary, and some carry a mere acknowledgment of work done. We all like to think of education as so attractive in itself, and so far producing in our pupils a thirst for more knowledge gained in a freer and larger way than is possible in schools. Moreover, we wish the museums to be the centres of diffusion of knowledge and the meeting-place of kindred spirits. There appears to be no good reason to be urged against the view that the State should, for services of this kind well rendered, provide an adequate sum for recompense, and it should be possible for our local authorities to hand over an

adequate sum to the trustees of local museums which are willing thus directly to help forward and expand the higher science teaching of our schools, corresponding control being, of course, in every case given for the proper disbursement of the assigned money. This work is at any rate as well worthy of such support as are free libraries, or municipal bands, or art-galleries, to which, of course, I have not the slightest objection.

Summing up my points, I should like the great interest in Nature study which has lately sprung up to be linked definitely with the museums, that these may help the movement and in return be helped themselves ; that the provision made by curators should be wisely curtailed and definitely directed ; that the professional instinct and pride of the science teachers should be called upon to assist in a great work ; and that the success of the movement should not be imperilled by the premature uprising of the false economist, who has had no opportunity of seeing what other nations can do, and who wishes to appraise the value of any work by its immediate value in current coin.

Mr. G. P. Hughes (Warwickshire Naturalists' Club) said that the paper which had been read had come most opportunely in his case, for it dealt with a subject which had occupied his thoughts and attention for some time past. He dwelt on the importance of giving an interest to the younger generation in country places, and of getting the minds of the young people trained to the industrial interests which they must follow out in after life. If the children of the labouring classes were merely taught a few of the ordinary lessons of schools, then interest would not be directed towards what their future life is likely to be. He held that schoolmasters should have some acquaintance with scientific pursuits, and by the aid of museums, which in many parts of the country were dormant, these children might be brought gradually to take a much keener interest in their future life than they do at the present moment.

The Rev. G. Capell remarked that he had been a school-manager for about thirty-four years, and had always felt that the difficulty was that no science was introduced by which the minds of the children could be trained and so fitted for the pursuits they were afterwards to enter into. He had been in a district in the North of France, and was immensely struck by the care taken by the French Government to train children in a knowledge of those pursuits which they were to follow in after life. There is a most elaborate system of teaching, including, in addition to scientific training, the practical use of the machinery which they will have to use in cultivating the land and in various other industries. In Germany it is the same. The children's minds are trained practically and scientifically. That is what we want more of in England ; the practical and the scientific should go together. The difficulty is that schoolmasters have not been trained in that way themselves. The speaker thought that attention must be directed to this in future, and the museums would be wonderfully useful in helping masters in order that they might be better prepared to instruct the children.

Mr. F. W. Rudler (Essex Field Club) explained that when in 1891 the Museums Association held its annual meeting in Cambridge, he ventured to refer to the difficulties incidental to museum-demonstration ; and he was glad to find that a method somewhat similar to that which he suggested had been successfully carried out at Leeds. He held that the demonstration should usually be given in a separate lecture-room, and be

followed by adjournment to the museum. Every museum should be associated with a theatre provided with lantern and other necessary appliances. The interest of the museum-question in connection with the Delegates at this Conference seemed to centre in the point of contact between the local museum and the local Society. How could the one assist the other? The speaker referred to the excellent practice in certain museums of exhibiting fresh wild flowers with instructive labels—a source of much interest to young visitors. This, he held, was a department of work which could well be undertaken by the local Natural History Society. Ladies of leisure, taking an intelligent interest in botany, might assist the curator by undertaking to contribute a constant supply of fresh specimens and to furnish them with appropriate labels. Such labels, judiciously written, might convey much useful knowledge in a pleasant form, and would be read and copied by intelligent children. Although it is a great thing to bring the children to the museum, it must be remembered that there is another aspect of the question: the museum may be taken with excellent results to the children. He therefore advocated the circulation of small loan-cabinets of simple specimens—which might be arranged and distributed by the Natural History Society to the schools. The local Society might do much to relieve the curator, who was generally much overworked and very much under-paid. Every effort to increase the usefulness of the museum laid additional work upon his shoulders; and the speaker was glad that Mr. Johnson had proposed that museum-demonstrations to schools should be adequately paid for.

Mr. Hopkinson referred to the Hertfordshire County Museum. At least one half of the 200 or 300 visitors per week were school children. They came in from the Board schools during meal-times, and quickly detected any additions made to the collections, which showed that they took a very great interest in the museum. Sometimes they brought all sorts of things they had collected, but at first almost worthless. For instance, they brought shells with the living animals in them. They were then instructed how to remove them, and were now bringing clean shells and sometimes really good specimens of the different varieties of land mollusca. This showed how a museum would attract children, and no doubt produce good educational results.

The Rev. R. Ashington Bullen observed that, in the little parish where he lived, about a quarter of an acre of land was rented and the children were being taught agricultural pursuits. He did not think that they must take a pessimistic view of the education of the children in the country districts, for he believed that a great deal was going on there about which people in general know nothing.

Mr. Whitaker remarked that, being lately in a little village in Shropshire, he had a conversation with a woman who told him that they encouraged the children not only to collect, but to bring in objects to the school, where they were kept in a case for a certain time. It occurred to him that this was an excellent method of interesting the children and developing a taste for museums.

Second Conference, August 23, 1904.

Principal E. H. Griffiths, F.R.S., in the chair, followed by Dr. Tempest Anderson, B.Sc.

The Corresponding Societies Committee was represented by Mr. W. Whitaker, Rev. T. R. R. Stebbing, Rev. J. O. Bevan, Mr. John Hopkinson, Dr. H. R. Mill, Mr. T. V. Holmes, and Mr. F. W. Rudler.

Principal Griffiths, in opening the proceedings, said that he had ventured to take a certain kind of action of his own initiative since their last meeting, which he was going to ask the Conference to be good enough, if they thought fit, to confirm. He thought the remarks that were made on the proposal which he put before the Congress from the chair at the last meeting led to the conclusion that the Delegates would uphold, and were in sympathy with, the view that we ought to bring a larger number of our Societies into touch with the British Association, and that the union between the Society and the British Association should be a more real one than it is at present. The speaker ventured to translate the opinion of the meeting as that, and there was no voice to the contrary. On the other hand the question he put forward of the possibility of establishing a 'Journal of Corresponding Societies' was obviously one on which there were many differences of opinion ; but in any case, it must be remembered that the Conference could take no action without the Council of the Association. The Chairman thought it was inadvisable to put things off until next year, because it would be very difficult to get anything like the ordinary business done then, and unless he had submitted a recommendation to the Committee of Recommendations before its meeting yesterday, all opportunity of doing anything would have been practically lost for the next two years. Therefore, on his own responsibility—and he stated at the time that it was on his own responsibility—he handed in a notice to go on the agenda paper of the Committee of Recommendations to the following effect :—

'That a Committee be appointed, consisting of members of the Council of the Association, together with representatives of the Corresponding Societies, to consider the present relation between the British Association and local Scientific Societies.

'That the Committee be empowered to make suggestions to the Council with a view to the greater utilisation of the connection between the Association and the affiliated Societies, and the extension of affiliation to other Societies which are at present excluded under Regulation I.'

It would greatly strengthen his hands in the Committee to which he was then going if the Delegates would empower him to say that they supported the resolution. Of course it would commit the Delegates to nothing, because it was only asking for a committee to inquire into the whole matter, and unless this action were taken immediately nothing practically could be done for two years. He therefore asked the Delegates to intimate, unless they had any opposition to offer, by a show of hands that he had their authority to present this resolution.

The resolution was carried unanimously and with applause.

The Chairman then said that if this were agreed to by the Committee of Recommendations it would be necessary for the Delegates to appoint representatives to meet the members of the Council in this

matter. Therefore he would ask the Delegates that afternoon to pass a formal resolution that, if this resolution were adopted by the General Committee, certain persons be appointed as representatives of the Delegates upon that Committee. It would be for that meeting to suggest the names. He suggested that they should not appoint too many, and that they should be such as would be fairly certain to attend the meetings.

After a hearty vote of thanks had been passed to the Chairman for the action he had taken, he vacated the chair in favour of Dr. Tempest Anderson.

It was unanimously resolved that, if the resolution referred to were passed by the General Committee, the following Delegates be appointed as representatives of the Corresponding Societies on the proposed Committee—namely, the Chairman of the Conference of Delegates, Principal E. H. Griffiths; the Chairman of the Corresponding Societies Committee, Mr. W. Whitaker; and the Secretary of the Committee and of the Conference, Mr. F. W. Rudler.

Mr. John Hopkinson, F.L.S., F.G.S., introduced the following subject:—

On the Conformity of the Publications of Scientific Societies with certain Bibliographical Requirements.

A few years ago I suggested for discussion at our Conference the subject of Dew-ponds; and although we had a very interesting discussion upon them I heard it remarked that it was scarcely of sufficient general interest to the Corresponding Societies.

The subject of my remarks on the present occasion should be of interest to all our Societies, and it is an eminently practical one; but I must confess that it is drier than Dew-ponds are, or should be. I will introduce it by giving a recent experience of my own, chiefly as an illustration of the requirement that the title of a paper should give as clear an idea of its contents as can be given in a few words.

I am compiling, for a work to be published by the Ray Society, a Bibliography of the Freshwater Rhizopoda. I knew that in the 'Monthly Microscopical Journal,' for ten years the organ of the Royal Microscopical Society, there was a paper on a presumed freshwater rhizopod from the New Forest to which the name *Pseudo amœba violacea* had been given, but I could not remember the title of the paper or the author's name. I searched the indexes to twenty volumes under the catch-words 'Protozoa,' 'Rhizopoda,' '*Pseudo-amœba*,' 'Freshwater,' and 'New Forest.' Under not one of these could I find a reference to the paper, and it was only by turning over the pages that the plate illustrating it caught my eye in vol. x. The paper is by Dr. R. L. Maddox, and its title is 'On an Organism found in Fresh-pond Water.' It is indexed only under 'Maddox' and 'Organism.' There are three faults here to which I wish to draw your attention. One is the absence of a table of contents and of a list of the plates. Such a table is, or should be, very much shorter than an index, and it enables a paper on any particular subject to be found much more readily than by the index. Another is the meagre indexing; and the third is the unsatisfactory title of the paper. The newly-proposed genus does not appear in either title or index, there is no indication of the kind of organism—believed to be

a rhizopod—nor of the locality in which it was found. The title should have been something like this: 'On *Pseudo-amœba violacea*, a presumed new Freshwater Rhizopod from the New Forest,' and the principal words in this title, at least, should have been indexed.

I need scarcely explain how all who write similar papers, and all editors of the publications of Scientific Societies, may apply this criticism and relieve the labours of others, especially of compilers of bibliographies.

I have examined the bound volumes of most of your publications at the Office of the Association, and I find that the majority have the very serious fault that the date of publication of the several numbers, or parts, of which they are composed, is not given. The dates may have been, and probably in most cases were, on the covers; but the covers are not bound up in the volumes, as they ought to have been—the first leaf at least—which would give date and contents, and should preferably be bound at the end of each volume. When the dates are not given in the bound volume it is impossible to ascertain when any particular paper was published, and therefore impossible to enter it in a bibliography as it should be entered. This may be of great importance in questions of priority. The month and year of issue of each separate part of which the volume consists, with the number of the first and last page in each part, should always be printed after the title-page or table of contents and list of plates; thus, for example—

Part I., pp. 1–48	. . . . . .	October 1904.
„ II., „ 49–80, ix–xvi	. . . . .	January 1905.

This might obviate the *necessity*, if not the advisability, of binding the covers.

A volume sometimes appears without an index, more often without a table of contents and a list of the plates or other illustrations. Occasionally the index is placed at the beginning of the volume; it should always be at the end. In one case at least a table of contents is called an index; in another that abomination, a collection of separate indexes, is called 'indices,' a term which should be restricted to its mathematical signification.

A frequent fault is the separate pagination of a thin publication, usually called 'Annual Report and Proceedings,' or 'Annual Report and Transactions,' the first part of which titles is superfluous. When, say, ten of these, of perhaps thirty pages or so each, are bound together to form a volume, how difficult it is to ascertain their contents, how difficult it would be to satisfactorily index the volume! Much rarer is the fault of making a volume so thick that it has to be bound in two.

Occasionally the name of an author is given thus: 'Mr. Myth read the following Paper on Sea-serpents.' Initials should always be given. Occasionally the name of an author is omitted altogether. This is the case with an annual meteorological report which appears in a very useful publication called a 'Record of Bare Facts,' issued by an energetic Corresponding Society.

Now a few words about reprints. I receive one. It is paged 1 to 4. It is stated, on the cover only, to be from the proceedings of a certain Society, neither volume nor date being given. I wish to enter it in a bibliographical list. Reference to the publication from which it is reprinted is absolutely necessary. I cannot find it in any London library.

Eventually I get the required information from the Secretary of the Society. The reprint has not only been re-paged, but the position of the type on the pages has been altered so as to get into four pages a paper running into five—a great temptation certainly. But in all reprints, except perhaps reports of proceedings which would never have to be entered in a bibliography, the original pagination should be retained, and the title of the publication, the volume, and the date—month and year—should be printed on the paper, as well as on the cover, so that it remains if the cover be taken off, as for binding.

There is one other point I should like to impress upon you. Your proceedings should be *published*; that is, it should be possible to purchase them. They are then amenable to the copyright laws; copies have to be presented to five libraries—one in London, one in Oxford, one in Cambridge, one in Edinburgh, and one in Dublin. That in London is the British Museum Library; and even if you only print and do not publish your proceedings, a copy should be sent there. This is a point I cannot too strongly urge.

We possess, at the Office of the Association, a very valuable and unique collection of the Proceedings of the Corresponding Societies. I hope that it will in future be kept intact, and that by more extensive and convenient premises being acquired by the Association it may be possible to improve its arrangement and make it more accessible than it is at present, and I also think that an effort should be made to get replaced certain publications which some years ago were lent and lost, so that every paper catalogued in the Reports of the Association may be readily referred to, for some of them are not now to be found in London, not even in the library of our greatest national institution, the British Museum.

Mr. W. Whitaker said he should like to support what Mr. Hopkinson had stated. The speaker had wasted much time in trying to find where a paper came from in order that he might be able to quote it properly, and in many instances he had taken his separate copy to a library where the journal existed and collated it himself with the original. When one has to republish a paper it is inconceivably inconvenient to shift the type, as printers will do. Societies and editors of papers should make printers understand that they cannot do as they like in these matters. Mr. Hopkinson spoke of the Library of the British Museum. Not long ago the speaker sent some annual reports of a provincial Society to the British Museum and they were returned! They were not entered at Stationers' Hall, and were not wanted at the Museum. The Library is so full that little things formerly received cannot be accepted now.

The Rev. T. R. R. Stebbing thought that if sent to the British Museum at South Kensington they would be received most gratefully.

Mr. Whitaker observed that that is a different thing. He thought the Trustees of the future would very much regret the action of the Trustees of the present, because these thin pamphlets become so difficult to get hold of in years to come. He hoped the Delegates would notice what Mr. Hopkinson had said, and try to get the Societies to adopt some kind of system in editing. There is an opinion about that anyone can edit a journal. That is the greatest mistake possible. It requires a good deal of technical knowledge. A man can be a good writer and good reader, and yet make the worst possible editor. He had told several Societies of these defects and they had been remedied. It is for the

good of the Societies that the Delegates should try to get their journals printed in a regular orthodox fashion, with contents in front and index at the end. And do not go re-paging from No. 1 every single yearly issue. A Society which he had represented had committed this error for the last four years, and had occasioned him much inconvenience. The parts should be paged continuously, so that they may form a much more dignified kind of volume. When each part is paged separately, the only thing to be done is to put, in binding them, a stiff piece of coloured paper between each number and the next, otherwise it takes a long time to find any particular part.

Mr. T. W. Shore (Hampshire Field Club) said that as one who worked a good deal in the British Museum he thought they might do a little more than Mr. Whitaker had suggested. He had not had any experience of the publication of pamphlets, but he did know the extreme use of them, having been for some eight years a constant worker in the reading-room. He thought that the Delegates, as a Conference, might represent to the authorities of the British Museum that they were losing some out-of-the-way information of a very valuable kind in some of the Societies' publications; and might ask them to reconsider their position, and to receive the publications, however small, of any Society.

The Rev. T. R. R. Stebbing said that his own experience was that the Museum had not got room for its books and pamphlets, and did not care for any more. Moreover, if these pamphlets are filed there, you have to wait perhaps half or three-quarters of an hour before you get what you want. But if you go to the British Museum at South Kensington, and apply to the Librarian there, you probably get whatever you want in two or three minutes. The speaker knew that instead of rejecting pamphlets and reports and transactions every possible trouble was taken at Kensington to collect them. They are there all brought together in a small compass; but if they go to Bloomsbury the messenger may have to travel miles before he alights upon what is wanted. There was one point he thought Mr. Hopkinson intended to insist upon, and that was the *form* of reports and transactions. It is extremely inconvenient to have different sizes. You do not know how to bind them up. He believed that the Royal Society itself was going to change the form of its proceedings, and he thought if our Societies were to apply in a modest way to the large London Societies for advice as to the form it is best to adopt, a uniform size might be adopted which would be a very considerable advantage for our book-shelves.

Dr. G. Abbott inquired to what extent the Library of the British Association was used. He was suspicious that really the volumes sent there would be very much more appreciated if they were sent to South Kensington. Perhaps, however, both could be supplied.

Mr. J. F. Tocher (Buchan Field Club) remarked that he had listened with great pleasure to Mr. Hopkinson's paper, and thought that an endeavour should be made to carry out some of his suggestions. As editor of the transactions of a Corresponding Society, he had felt guilty as to one or two points with regard to the publication. In his Society they did not put the number of the volume upon reprints. Otherwise he thought the Buchan Field Club attended to most of the points that were brought out. So far as the form of the transactions was concerned, he thought they would experience some difficulty with the Corresponding Societies. In the North of Scotland they had at least half a dozen Societies and half

a dozen different forms of transactions. He thought there would be great difficulty in getting Societies to agree to any particular form unless the British Association gave them a definite standard form in which to publish their transactions.

The Vice-Chairman (Dr. Tempest Anderson) said that the size of publications was one of the most pressing importance. He had been getting a considerable quantity of literature on the Martinique eruptions. The variety of sizes of these publications was heartrending. It was almost impossible to find anything approaching uniformity. When you take the magazine articles it is astonishing how much more uniformity prevails. Here, said the speaker, is the 'Geographical Journal.' That is probably one of the best sizes, but it is about half an inch too narrow. The corresponding journal in America is half an inch wider, and is able to have really good plates put in. The Journal of the Geographical Society cramps the size, and in these days of photography the extra half-inch improves the scale wonderfully. However, though the Royal Society, for instance, were to recommend all the other Societies to adopt uniformity, it is certain we should never get the public at large to press for an alteration in the size of their favourite magazines. He thought the size of the 'Century' was about the average size of the magazines, and it would be very much better if all magazines were to keep to that size. As it is practically impossible to get the magazines to change their form, he considered it would be a good thing if Societies would adopt the average size of the magazines and keep to it. He complained that the two Guide-books for the British Association meeting were each of a different size. Then the excursion programmes, which one would like to bind up as souvenirs of this meeting, were yet again of a different size.

Mr. Hopkinson, in reply, said he had purposely excluded all reference to the size of publications, because that had been thoroughly discussed some years ago by a very influential committee, whose Report was presented at the Ipswich Meeting of the British Association in 1895 (p. 77). Demy octavo ($8\frac{3}{4}$ inches by $5\frac{5}{8}$ inches) or demy quarto ($11\frac{1}{4}$ inches by $8\frac{3}{4}$ inches) was the size recommended by the Committee. The smaller size was that of the British Association Reports and of the publications of a very large number of other Societies.

Mr. Stebbing rather thought that public opinion had considerably changed since the date of this Report, and that a larger size was now wanted.

Mr. Hopkinson said that it had at all events been decided as the standard size of the British Association, and he did not think it would be of any use to discuss the subject further. With regard, however, to sending the proceedings of Societies to the British Museum, he remarked that everything published in this country ought to be sent there—to the National Library—for in order to consult books we did not want to go to South Kensington, which is miles away. He admitted that Mr. B. B. Woodward had done excellent work in endeavouring to get the whole of the publications of the Societies, and he hoped that the Delegates would send their publications there also; but still they must not omit the British Museum in Bloomsbury. Mr. Hopkinson proceeded to refer to the assistance he had received from the Library Catalogue of the Natural History Museum in his search for information which he had been unable to obtain at the British Museum owing to the latter having neglected to bind the covers of a book issued in parts, and he urged the importance of

binding the covers of scientific magazines to preserve the lists of contents as well as the dates of issue. He regretted to find that the British Museum, instead of binding the first cover of each number had lately only bound the cover of the first part and the last part, usually the one in January and the other in December. The only other point Mr. Hopkinson wished to draw attention to was this, that the Office of the British Association was, after all, the best place at which the transactions of the Corresponding Societies could be kept. Every year the titles of a selected list of papers from these transactions are published in the Report of the British Association, and if anyone wants to refer to a paper in that list he knows at once where it can be seen—at the Office of the Association. Therefore he thought it was most important that the publications should be kept there, where they are bound and carefully preserved, the cost of binding them being defrayed out of the annual grant to the Corresponding Societies Committee.

The Reports of the Delegates from the various Sections were then received.

Dr. H. R. Mill, representing Section A, explained that this Section was composed this year, as it had been for some time past, of two Sub-sections. The Conference of Delegates naturally came more immediately into contact with the Sub-section called, for want of a better name, Cosmical Physics, and the Committee of that Section desired him to convey to the Delegates their feeling of the value of the work that had been done by the Corresponding Societies. Although there was no specific question to be laid by the Section before the Delegates, the representative was given a free hand to make any remarks he considered appropriate to the occasion. He would refer only to meteorological observations. A number of the Societies represented there, notably those with which Mr. Hopkinson and Mr. Whitaker were connected, had given a great deal of attention to this question of meteorology, and had published each year a most admirable meteorological report of the areas they dealt with. A number of other Societies dealt with the same subject nearly as completely, and others in a more fragmentary fashion, but there was room for a great deal of improvement. The Royal Meteorological Society was endeavouring to improve the position of this country in this respect, to increase the interest in observation, and to direct it systematically. They had sent out a circular in which four questions were put to the Fellows of the Society. When these were brought before the local Societies the speaker trusted that the Delegates would reinforce the action of the Fellows of the Royal Meteorological Society who approached them, and would at any rate discuss the matter. If they needed any information on the subject they should refer either to the Assistant-Secretary, Mr. Marriott, to the speaker, or to any of the officials of the Society, and that information would be furnished. He hoped on a future occasion it might be possible to make more definite suggestions than at present. The subject was one of great interest. The observations were easily made, and when brought together could be put to excellent scientific use.

Mr. Whitaker (Section C) explained that it was the joint desire of the Geographical and Geological Sections to get a Committee appointed to determine and record the exact significance of local terms applied to topographical and geographical objects. All members of the Corresponding Societies must meet with such terms, and the Delegates are naturally

the very people to help in this matter. They should record these words and send them up to the Secretary of the Committee or to the Secretary of the British Association. As an example, Mr. Whitaker said that when he was working in the neighbourhood of Southampton there was one term that he heard confined to a little district round Southampton; a term applied to the bleached top of a gravel, which was known there as 'skyōne.' How it is spelt and what it is derived from he had not the least idea; but the name had a definite meaning there, and an economic meaning, because that particular sort of gravel was used for a particular object. It was interesting and ought to be recorded. Every one of the Delegates would find in their own districts some such terms, sometimes spread over a county, sometimes over a small district, sometimes over three or four counties, and it would be desirable to get at what they really meant and how they had been derived. He thought it would be interesting not only to geographers and geologists, but to students of folklore and similar subjects.

The Rev. T. R. R. Stebbing explained that Section D had appointed a Sub-Committee, which eventually drew up the following report:—

'August 22, 1904.

'A meeting of the Sub-Committee appointed to prepare a reply to a letter from Mr. Rudler was held to-day. Messrs. Stebbing, Knubley, and Bles were present.

'It appears that several subjects for work by local Societies have been proposed to the Conference of Delegates of Corresponding Societies by representatives of Section D at former meetings without producing any substantial results.

'Four subjects suggested already are:

'1. Cave faunas: report to Rev. T. R. R. Stebbing, Ephraim Lodge, The Common, Tunbridge Wells.

'2. Zoological changes on a given plot of land during the year: report to Professor Miall, The University, Leeds.

'3. Compilation of local faunas. A complete working scheme has been prepared, and is actually in operation in some localities. For particulars of schedules, &c., apply to Mr. Edward J. Bles, The University, Glasgow.

'4. Systematic observations on the micro-organisms of a given pond or ditch: report to Professor West, Agricultural College, Cirencester.

'In addition to the above the Sub-Committee suggest the two following subjects:

'5. Overland lines of migration of birds: report to Rev. E. P. Knubley, Steeple Ashton Vicarage, Trowbridge.

'6. Collection of slugs from all parts of the British Isles: apply for information to Mr. W. Denison Roebuck, Hyde Park Road, Leeds.'

Mr. Stebbing mentioned, in conclusion, that he would be much indebted to any member who lived in the neighbourhood of caves through which there might be flowing streams if they would let him have some information concerning the same and the fauna, and if there happened to be crustaceans he would like to have specimens.

Dr. Herbertson (Section E) said that after Mr. Whitaker's clear statement little remained for him to add to the request that the Corresponding

Societies should send to the Joint Committee of Section E and Section C information as to the local names of geographical and topographical forms. But there was one other point he should like to bring before the members of the Corresponding Societies, and that was the desirability of sending to the Royal Geographical Society reports and copies of any of their publications which contained papers dealing with questions of distribution, so that these might be noticed in the Bibliography of Geography which is prepared by the Librarian of the Society. Extracts of some of the papers might then appear in the Monthly Notes, and thus be communicated to the geographers of this country.

Miss Ethel Sargant said that she was not the representative of Section K, but Mr. Stebbing had asked her to report as to the information she had received with regard to orchids in reply to the appeal which had been made on a former occasion. The only communication she had received was from a Tunbridge Wells member. She had also, after many inquiries, got a little information with regard to the leaves of orchids; but none about the seedlings, respecting which information had been also solicited.

The Rev. J. O. Bevan moved a vote of thanks to the Master and Fellows of Gonville and Caius College for the services they had rendered to the Conference by enabling them to meet in that interesting room and allowing them likewise to gather in the small library, which some of them had taken advantage of. There were various reasons why they should give that vote; one was that the College had introduced them to the information that Humility and Virtue lead to Honour.

Mr. Hembry cordially seconded the vote, and the motion was carried with enthusiasm.

The Rev. T. R. R. Stebbing moved, and Mr. Hopkinson seconded, a vote of thanks to the Chairman, which was carried with applause and briefly acknowledged.

The Corresponding Societies of the British Association for 1904–1905.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. R. Barnett Johnstone and T. Nisbet	261	None	2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	J. Langfield Ward, Royal Literary and Scientific Institution, Bath	80	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, M.R.I.A.	242	None	1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. N. H. Foster and James Orr.	375	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Rev. J. J. M. L. Aiken, B.D., Manse of Ayton, Berwickshire	400	None	10s.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.	Alfred Cresswell, Birm. and Midland Inst., Paradise Street, Birmingham	140	None	1l. 6s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers, Congreve Street, Birmingham. W. P. Marshall and W. B. Grove, M.A.	174	None	1l. 1s.	Proceedings, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	S. H. Reynolds, M.A., University College, Bristol	152	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	170	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	B. L. Oswell, 5 Balmoral Road, Burton-on-Trent	210	None	5s.	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury	168	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	William Sheen, M.S., 2 St. Andrew's Crescent, Cardiff	450	None	15s.	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shepheard	1011	None	5s.	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	The Museum, Public Buildings, Penzance. John B. Cornish	96	None	1l. 1s.	Report and Transactions, annually.
Croydon Natural History and Scientific Society, 1870	Croydon N. H. Soc.	Public Hall, Croydon. G. W. Moore	200	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Rev. Herbert Pentin, M.A., Milton Abbey Vicarage, Dorset	361	10s.	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	J. de W. Hinch, National Library of Ireland, Dublin	154	5s. Assoc. none	5s. Associate 2s. 6d.	'Irish Naturalist,' monthly; Report, annually.
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	A. Lander, The Medical Hall, Canterbury	102	None	10s.	Transactions, annually.
Eastbourne Natural History Society, 1867	Eastbourne N. H. Soc.	E. J. Bedford, Anderida, Gorringe Road, Eastbourne	120	2s. 6d.	7s. 6d.	Transactions, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	India Buildings, Edinburgh. James Currie, M.A., F.R.S.E.	200	10s. 6d.	12s. 6d.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association	Elgin Lit. Sci. Assoc.	R. B. Gordon, Elgin	98	None	5s.	Transactions, occasionally.
Essex Field Club, 1880	Essex F. C.	William Cole, Springfield, Epping New Road, Buckhurst Hill, Essex	300	None	15s.	'Essex Naturalist,' quarterly; 'Special Memoirs,' &c., occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Newton-Mearns, Glasgow	250	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	Alex. Ross, 2 Kennyhill Gardens, Dennistoun, Glasgow	297	None	7s. 6d.	Transactions and Proceed-

Glasgow, Royal Philosophical Society of, 1802	Glasgow R. Phil. Soc.	Dr. Freeland Fergus, 207 Bath Street, Glasgow	1,000	1*l*. 1*s*.	1*l*. 1*s*.	Proceedings, annually.
Halifax Scientific Society, 1874	Halifax S. S.	Literary and Philosophical Society's Rooms, Harrison Road. F. Barker	150	None	2*s*. 6*d*.	'Halifax Naturalist,' every two months.
Hampshire Field Club and Archæological Society, 1885	Hants F. C.	W. Dale, F.S.A., 5 Sussex Place, Southampton	250	None	7*s*. 6*d*.	Proceedings, annually.
Haslemere Microscope and Natural History Society	Haslemere Mic. N. H. Soc.	Rev. G. B. Stallworthy, The Manse, Hindhead, Surrey	400	None	Minimum 2*s*.	Report, annually; Science Papers occasionally.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	A. E. Gibbs, F.L.S., St. Albans, and A. Sutton, Watford	200	10*s*.	10*s*.	Transactions, four times a year.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	G. E. Frisby, 1 Claudeboye Villas, Fengates Road, Redhill	108	10*s*. and 5*s*.	10*s*. and 5*s*.	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	J. W. Stather, F.G.S., 16 Louis Street, Hull	75	None	5*s*.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F. N. C.	T. Sheppard, F.G.S., The Museum, Hull	180	None	5*s*.	Transactions, annually.
Institution of Mining Engineers, 1889	Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,800	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	195	None	5*s*.	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. Lawson, Dr. N. M. Falkiner, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1*l*.	Journal, annually.
Leeds Geological Association, 1873	Leeds Geol. Assoc.	Law Institute, Leeds. Walter Parsons	84	None	5*s*.	Transactions, occasionally.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	J. M. Butler, 214 Tempest Road, Leeds	90	None	6*s*.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. W. A. Evans	333 Membs. & Associates	None	Members 1*l*. 1*s*.; Associates 10*s*. 6*d*.	Transactions, half-yearly.
Liverpool Engineering Society, 1875	Liverpool E. Soc.	R. C. F. Annett, 4 Buckingham Avenue, Sefton Park, Liverpool	535	None	Resident 1*l*. 1*s*. Non-Res. and Students 10*s*. 6*d*.	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Liverpool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Bldgs., Liverpool	700	None	Members 1*l*. 1*s*. Associates 10*s*. 6*d*.	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liverpool Geol. Soc.	Royal Institution. W. A. Whitehouse	66	None	21*s*.	Proceedings, annually.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	T. E. Acheson, Lloyds Bank, Ramsey, Isle of Man	120	2*s*. 6*d*.	7*s*. 6*d*. and 5*s*.	Yn Lioar Manninagh, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	F. Zimmern and J. H. Reed, 16 St. Mary's Parsonage, Manchester	700	None	Members 1*l*. 1*s*.; Associates 10*s*. 6*d*.	Journal, quarterly; 'Geography,' monthly.
Manchester Geological and Mining Society, 1838	Manch. Geol. Min. Soc.	5 John Dalton Street, Manchester. W. Saint and J. Tonge, jun.	253	None	1*l*.	Transactions, monthly.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, and A. E. Thompson, Wellington Road, Whalley Range, Manchester	194	5*s*.	6*s*.	Transactions and Report, annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	Theodore Gregory, 3 York Street, Manchester	210	10*s*. 6*d*.	10*s*. 6*d*.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick	250	1*s*. 6*d*.	3*s*. and 5*s*.	Report, annually.
Midland Counties Institution of Engineers, 1871	Mid. Count. Inst.	G. Alfred Lewis, Albert Street, Derby	420 Membs., Associates, & Students	1*l*. 1*s*. None	Members 31*s*. 6*d*.; Associates and Students 20*s*.	Transactions of Institution of Mining Engineers, monthly.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Mining Offices, Regent Street, Barnsley	300	None	1*l*. 10*s*.	Transactions of Inst. of Mining Engineers, monthly.

CORRESPONDING SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich	256	None	5*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,400	None	25*s.* and 42*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club	N. Staff. F. C.	W. Wells Bladen, Stone, Staffs	469	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	Northants N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	260	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of	Northumb. N. H. Soc.	Hancock Museum, Newcastle-on-Tyne. Prof. M. C. Potter, M.A., and N. H. Martin, F.L.S.	450	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Prof. J. W Carr, M.A., University College, Nottingham	188	2*s.* 6*d.*	5*s.*	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	500	5*s.*	7*s.* 6*d.*	Report, annually; Meteorological Obs., occasionally.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	399	2*s.* 6*d.*	5*s.* 6*d.*	Trans. and Proc. annually.
Quekett Microscopical Club, 1865	Quekett Club	A. Earland, Reading Villa, Denmark Street, Watford	380	None	10*s.*	Journal, half-yearly.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, D.Sc., 105 Freehold Street, Rochdale	248	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	182	None	5*s.*	'Rochester Naturalist,' quarterly.
Somersetshire Archæological and Natural History Society, 1849	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble, Rev. F. W. Weaver, and C. Tite	615	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	G. M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union	Rev. R. Ashington Bullen, B.A., Pyrford Vicarage, Woking	42 Societies	None	Minimum 5*s.*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society	Southport Lit. & Phil. Soc.	A. H. Garstang, 20 Roe Lane, Southport	151	None	5*s.*	Proceedings, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M.Inst.C.E., 3 Newhall Street, Birmingham	178	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.
Toronto, Astronomical Society of, 1884	Toronto Astr. Soc.	Canadian Institute Building. J. R. Collins	125	None	2 dollars	Transactions, annually.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,200	None	10*s.* and 5*s.*	Journal, annually.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	Museum, Warwick. C. West, Cross Cheaping, Coventry	99	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	240	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, M.A., F.G.S., Hopton, Mirfield	184	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	The Museum, Hull. T. Sheppard, F.G.S.	400 and 2,650 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	420	None	2*l.*	Report, annually.

Catalogue of the more important Papers, and especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1904.

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

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ALLEN, H. STANLEY. The Theory of Ions or Electrons. 'Proc. Glasgow R. Phil. Soc.' XXXIV. 106–115. 1903.

ASHWORTH, J. R. Weather Warnings. 'Trans. Rochdale Lit. Sci. Soc.' VII. 97–100. 1903.

BLACK, W. G. Rainfall in 1901 (Edinburgh Central District). 'Journal Manch. Geog. Soc.' XVIII. 163–164. 1903.

BRIGHTON AND HOVE NATURAL HISTORY AND PHILOSOPHICAL SOCIETY. Meteorology of Brighton, July 1902 to June 1903. 'Rep. Brighton N. H. Phil. Soc. 1902–1903,' 32. 1903.

CAMPBELL-BAYARD, F. Meteorological Report for 1902. 'Trans. Croydon N. H. Sci. Soc. 1902–1903,' 63–70, and Appendices of Tables, 50 pp. 1903.

CARADOC AND SEVERN VALLEY FIELD CLUB. Meteorological Notes, 1903. 'Record of Bare Facts,' No. 13, 43–54. [1904.]

COLLINGWOOD, E. J. Meteorological Record for 1901 at Lilburn Tower, Northumberland. 'History Berwicksh. Nat. Club,' XVIII. 178. 1903.

CRAW, J. H. Notes of Rainfall and Temperature at West Foulden and Rawburn, 1901. 'History Berwicksh. Nat. Club,' XVIII. 177. 1903.

CRESSWELL, ALFRED. Records of Meteorological Observations taken at the Observatory of the Birmingham and Midland Institute, Edgbaston, 1903. 'Birm. and Mid. Inst. Sci. Soc.' 30 pp. 1904.

EATON, H. S. Returns of Rainfall, &c., in Dorset in 1902. 'Proc. Dorset N. H. A. F. C.' XXIV. 56–65. 1903.

FRYER, Dr. ALFRED C. A Dust-fall in the South-west of England. 'Proc. Bristol Nat. Soc.' X. 83–89. 1903.

GRAY, Prof. ANDREW. Entropy. 'Proc. Glasgow R. Phil. Soc.' XXXIV. 116–124. 1903.

GREY, GEORGE. Record of Barometer at Milfield, Northumberland, in 1901. 'History Berwicksh. Nat. Club,' XVIII. 176. 1903.

GRIFFITH, GEORGE L. Notes of Surveys and Levellings in Canada. 'Trans. Inst. Min. Eng.' XXVI. 552–564. 1904.

HALBAUM, H. W. G. The Common-sense Doctrine of Furnace-draught. 'Trans. Inst. Min. Eng.' XXV. 700–716. 1903.

HEYWOOD, H. Meteorological Observations in the Society's District, 1902. 'Trans. Cardiff Nat. Soc.' XXXVI. 1–19. 1904.

HOPKINSON, JOHN. Meteorological Observations taken in Hertfordshire in the Year 1902. 'Trans. Herts N. H. Soc.' XI. 213–221. 1903.

—— Report on the Rainfall in Hertfordshire in the Year 1902. 'Trans. Herts N. H. Soc.' XI. 227–235. 1903.

—— Some Recent Storms and Floods in Hertfordshire. 'Trans. Herts N. H. Soc.' XI. 239–244. 1903.

—— and FRANK LATCHMORE. The Meteor of the 13th of July 1902. 'Trans. Herts N. H. Soc.' XI. 244. 1903.

LANDER, A. Meteorological Notes for the Year ending September 30, 1903. 'Trans. E. Kent S. N. H. Soc.' III. 29–32. 1903.

LATHAM, BALDWIN. Croydon Bourne Flows, 44 pp. 'Croydon N. H. Sci. Soc.' 1904.

MARKHAM, C. A., and R. T. D. SMITH. Meteorological Report.—Observers' Notes. 'Journal Northants N. H. Soc.' XII. 79–85, 113–119, 1903; 146–152, 1904.

MARLOTH, Dr. R. Results of Experiments on Table Mountain for Ascertaining the Amount of Moisture Deposited from the South-east Clouds. 'Trans. S. African Phil. Soc.' XIV. 403–408. 1903.

MAWLEY, EDWARD. Report on Phenological Phenomena observed in Hertfordshire during the Year 1902. 'Trans. Herts N. H. Soc.' XI. 41–48. 1904.

MEACHEM, F. G. (S. Staff. Inst.) Underground Temperatures. 'Trans. Inst. Min. Eng.' XXV. 267–275. 1904.

MEYRICK, E. Meteorological Observations, 1903. 'Report Marlb. Coll. N. H. Soc.' No. 52, 84–104. 1904.

MITCHELL, Rev. J. C. Results of Meteorological Observations taken in Chester. during 1902. 'Report Chester Soc. Nat. Sci. 1902–1903,' 12–18. 1903.

—— Results of Meteorological Observations taken in Chester during 1903. 'Report Chester Soc. Nat. Sci. 1903–1904,' 14–20. 1904.

MUIR, Dr. THOMAS. Factorizable Continuants. 'Trans. S. African Phil. Soc.' XV. 29–39. 1904.

—— Developments of a Pfaffian. 'Trans. S. African Phil. Soc.' XV. 35–41. 1904.

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STEWART, C. M. A Note on the Quantities given in Dr. Marloth's Paper 'On the Moisture Deposited from the South-east Clouds.' 'Trans. S. African Phil. Soc.' XIV. 413–417. 1904.

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THACKER, S. L. The Dynamics of the Winding Engine. 'Trans. Inst. Min. Eng.' XXVI. 445–464. 1904.

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—— Table of Rainfall in Halifax for Twelve Years. 'Halifax Naturalist,' VIII. 100. 1904.

—— Table of Adopted Mean Temperature in Halifax for Twelve Years. 'Halifax Naturalist,' VIII. 101. 1904.

WHITTON, JAMES. Meteorological Notes, and Remarks upon the Weather during the Year 1901, with its General Effects upon Vegetation. 'Trans. Glasgow N. H. Soc.' VI. 313–329. 1903.

WINGENT, HARRY F. Presidential Address, 'The Theory of Three-colour Photography.' 'Rochester Naturalist,' III. 217–222. 1904.

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YOUNG, E. W. Observations on the Flight of Birds and the Mechanics of Flight. 'Trans. S. African Phil. Soc.' XIV. 419–423. 1904.

Section B.—CHEMISTRY.

BRAND, MARK (Mining Inst. Scot.). Calcination of Blackband Ironstone at Dumbreck. 'Trans. Inst. Min. Eng.' XXV. 253–258. 1904.

BRITTAIN, J. H. Manchester's Contribution to the Chemistry of the Nineteenth Century. 'Trans. Rochdale Lit. Sci. Soc.' VII. 4–9. 1903.

BROWN, JOHN. The Liquefaction of Gases. (Inaugural Address.) 'Proc. Belfast N. H. Phil. Soc. 1902–1903,' 21–29. 1903.

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KEEGAN, Dr. P. Q. The Chemistry of some Common Plants. 'The Naturalist for 1903,' 229–232. 1903.

MUIR, J. J. (N. Eng. Inst. Eng.) An Improved Forced Method of Treatment of Low-grade Copper Ores. 'Trans. Inst. Min. Eng.' XXVI. 40–44. 1903.

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Section C.—GEOLOGY.

ANDREWS, Miss MARY K. Notes on some Igneous Rocks in Down and Antrim. 'Proc. Belfast N. H. Phil. Soc. 1902–1903,' 51–57. 1903.

ARBER, E. A. N. (N. Eng. Inst.) The Use of Carboniferous Plants as Zonal Indices. 'Trans. Inst. Min. Eng.' XXV. 371–380. 1904.

BALDWIN, WALTER. *Belinurus bellulus* from Sparth, Rochdale. 'Trans. Manch. Geol. Min. Soc.' XXVIII. 198–202. 1903.

BARNES, J. On a Fossil Polyzoa from the Mountain Limestone, Castleton. 'Trans. Manch. Geol. Min. Soc.' XXVIII. 243–244. 1903.

—— The Microscopic Structure of Mountain Limestone. 'Trans. Manch. Mic. Soc. 1902,' 38–46. 1903.

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BURNS, DAVID (N. Eng. Inst. Eng.). The Gypsum of the Eden Valley. 'Trans. Inst. Min. Eng.' XXV. 410–428. 1903.

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CADMAN, JOHN (N. Staff. Inst. Eng.). The Occurrence, Mode of Working, and Treatment of the Ironstones found in the North Staffordshire Coalfield. 'Trans. Inst. Min. Eng.' XXVI. 106–119. 1903.

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—— Anniversary Address. [The Mining Industry of Cornwall.] 'Trans. Cornwall R. Geol. Soc.' XII. 728–736. 1904.

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EDWARDS, W. The Surface Geology of Cheshire in its relation to Agriculture. 'Proc. Liverpool Geol. Soc.' IX. 292–301. 1903.

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TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section.—Professor Horace Lamb, M.A., LL.D., F.R S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

The losses sustained by mathematical science in the past twelvemonth have perhaps not been so numerous as in some years, but they include at least one name of world-wide import. Those of us who were students of Mathematics thirty or forty years ago will recall the delight which we felt in reading the geometrical treatises of George Salmon, and the brilliant contrast which they exhibited with most of the current text-books of that time. It was from him that many of us first learned that a great mathematical theory does not consist of a series of detached propositions carefully labelled and arranged like specimens on the shelves of a museum, but that it forms an organic whole, instinct with life, and with unlimited possibilities of future development. As systematic expositions of the actual state of the science, in which enthusiasm for what is new is tempered by a due respect for what is old, and in which new and old are brought into harmonious relation with each other, these treatises stand almost unrivalled. Whether in the originals, or in the guise of translations, they are accounted as classics in every university of the world. So far as British universities are concerned, they have formed the starting-point of a whole series of works conceived in a similar spirit, though naturally not always crowned by the same success. The necessity for this kind of work grows, indeed, continually; the modern fragmentary fashion of original publication and the numerous channels through which it takes place make it difficult for anyone to become initiated into a new scientific theory unless he takes it up at the very beginning and follows it diligently throughout its course, backwards and forwards, over rough ground and smooth. The classical style of memoir, after the manner of Lagrange, or Poisson, or Gauss, complete in itself and deliberately composed like a work of art, is continually becoming rarer. It is therefore more and more essential that from time to time some one should come forward to sort out and arrange the accumulated material, rejecting what has proved unimportant, and welding the rest into a connected system. There is perhaps a tendency to assume that such work is of secondary importance, and can be safely left to subordinate hands. But in reality it makes severe demands on even the highest powers; and when these have been available the result has often done more for the progress of science than the composition of a dozen monographs on isolated points. For proof one need only point to the treatises of Salmon himself, or recall (in another field) the debt which we owe to such books as the 'Treatise on Natural Philosophy' and the 'Theory of Sound,' whose authors are happily with us.

A modest but most valuable worker has passed away in the person of Professor Allman. His treatise on the history of Greek Geometry, full of learning and

sound mathematical perception, is written with great simplicity and an entire absence of pedantry or dogmatism. It ranks, I believe, with the best that has been done in the subject. It is to be regretted that, as an historian, he leaves so few successors among British mathematicians. We have amongst us, as a result of our system of university education, many men of trained mathematical faculty and of a scholarly turn of mind, with much of the necessary linguistic equipment, who feel, however, no special vocation for the details of recent mathematical research. Might not some of this ability be turned to a field, by no means exhausted, where the severity of mathematical truth is tempered by the human interest attaching to the lives, the vicissitudes, and even the passions and the strife of its devotees, who through many errors and perplexities have contrived to keep alive and trim the sacred flame, and to hand it on burning ever clearer and brighter?

In another province we have to record the loss of Dr. Isaac Roberts, a distinguished example of the class of non-professional investigators who have left so deep a mark on British science, and on Astronomy in particular. None of us can be unaware of his long and enthusiastic devotion to celestial photography, of the beauty and delicacy of the results which he achieved, and of the wealth of unsuspected detail which they brought to light.

Finally, we have to lament the death, within the last few days, of Professor Everett, whose name will always be associated with one of the most successful tasks which the British Association has taken in hand—viz. the promotion of a uniform system of dynamical and electrical units. He acted as Reporter to the Committee which was entrusted with this question, and by his handbook on 'Units and Physical Constants' he has done more perhaps than anyone else to popularise and establish its recommendations. He was well known to most of us as a bright and genial presence at these meetings, and contributed numerous interesting papers on optical and other subjects. He was happy in retaining his scientific faculties undimmed to the last, and was engaged up to the time of his death on some problems of a geometrical kind, on point-assemblages, suggested by the study of the recent speculations of Professor Osborne Reynolds.

Of the various subjects which fall within the scope of this Section there is no difficulty in naming that which at the present time excites the widest interest. The phenomena of Radioactivity, Ionisation of Gases, and so on, are not only startling and sensational in themselves, they have suggested most wonderful and far-reaching speculations, and, whatever be the future of these particular theories, they are bound in any case deeply to influence our views on fundamental points of chemistry and physics. No reference to this subject would be satisfactory without a word of homage to the unsurpassed patience and skill in the devising of new experimental methods to meet new and subtle conditions which it has evoked. It will be felt as a matter of legitimate pride by many present that the University of Cambridge has been so conspicuously associated with this work. It would therefore have been natural and appropriate that this Chair should have been occupied, this year above others, by one who could have given us a survey of the facts as they at present stand, and of their bearing, so far as can be discerned, on other and older branches of physics. Whether from the experimental or from the more theoretical and philosophical standpoint, there would have been no difficulty in finding an exponent of unrivalled authority. But it has been otherwise ordered, and you and I must make the best of it. If the subject cannot be further dealt with for the moment, we have the satisfaction of knowing that it will in due course engage the attention of the Section, and that we may look forward to interesting and stimulating discussions, in which we trust the many distinguished foreign physicists who honour us by their presence will take an active part.

It is, I believe, not an unknown thing for your President to look up the records of previous meetings in search of inspiration, and possibly of an example. I have myself not had to look very far, for I found that when the British Association last met in Cambridge, in the year 1862, this Section was presided over by Stokes, and moreover that the Address which he gave was probably the

shortest ever made on such an occasion, for it occupies only half a page of the report, and took, I should say, some three or four minutes to deliver. It would be to the advantage of the business of the meeting, and to my own great relief, if I had the courage to follow so attractive a precedent; but I fear that the tradition which has since established itself is too strong for me to break without presumption. I will turn, therefore, to a theme which, I think, naturally presents itself—viz., a consideration of the place occupied by Stokes in the development of Mathematical Physics. It is not proposed to attempt an examination or appreciation of his own individual achievements; this has lately been done by more than one hand, and in the most authoritative manner. But it is part of the greatness of the man that his work can be reviewed from more than one standpoint. What I wish to direct attention to on this occasion is the historical or evolutionary relation in which he stands to predecessors and followers in the above field.

The early years of Stokes's life were the closing years of a mighty generation of mathematicians and mathematical physicists. When he came to manhood, Lagrange, Laplace, Poisson, Fourier, Fresnel, Ampère, had but lately passed away. Cauchy alone of this race of giants was still alive and productive. It is upon these men that we must look as the immediate intellectual ancestors of Stokes, for, although Gauss and F. Neumann were in their full vigour, the interaction of German and English science was at that time not very great. It is noteworthy, however, that the development of the modern German school of mathematical physics, represented by Helmholtz and Kirchhoff, in linear succession to Neumann, ran in many respects closely parallel to the work of Stokes and his followers.

When the foundations of Analytical Dynamics had been laid by Euler and d'Alembert, the first important application was naturally to the problems of Gravitational Astronomy; this formed, of course, the chief work of Laplace, Lagrange, and others. Afterwards came the theoretical study of Elasticity, Conduction of Heat, Statical Electricity, and Magnetism. The investigations in Elasticity were undertaken mainly in relation to Physical Optics, with the hope of finding a material medium capable of conveying transverse vibrations, and of accounting also for the various phenomena of reflection, refraction, and double refraction. It has often been pointed out, as characteristic of the French school referred to, that their physical speculations were largely influenced by ideas transferred from Astronomy; as, for instance, in the conception of a solid body as made up of discrete particles acting on one another at a distance with forces in the lines joining them, which formed the basis of most of their work on Elasticity and Optics. The difficulty of carrying out these ideas in a logical manner were enormous, and the strict course of mathematical deduction had to be replaced by more or less precarious assumptions. The detailed study of the geometry of a continuous deformable medium which was instituted by Cauchy was a first step towards liberating the theory from arbitrary and unnecessary hypothesis; but it was reserved for Green, the immediate predecessor of Stokes among English mathematicians, to carry out this process completely and independently, with the help of Lagrange's general dynamical methods, which here found their first application to questions of physics outside the ordinary Dynamics of rigid bodies and fluids. The modern school of English physicists, since the time of Green and Stokes, have consistently endeavoured to make out, in any given class of phenomena, how much can be recognised as a manifestation of general dynamical principles, independent of the particular mechanism which may be at work. One of the most striking examples of this was the identification by Maxwell of the laws of Electromagnetism with the dynamical equations of Lagrange. It would, however, be going too far to claim this tendency as the exclusive characteristic of English physicists; for example, the elastic investigations of Green and Stokes have their parallel in the independent though later work of Kirchhoff; and the beautiful theory of dynamical systems with latent motion which we owe to Lord Kelvin stands in a very similar relation to the work of Helmholtz and Hertz.

But perhaps the most important and characteristic feature in the mathematical

work of the later school is its increasing relation to and association with experiment. In the days when the chief applications of Mathematics were to the problems of Gravitational Astronomy, the mathematician might well take his materials at second hand; and in some respects the division of labour was, and still may be, of advantage. The same thing holds in a measure of the problems of ordinary Dynamics, where some practical knowledge of the subject-matter is within the reach of everyone. But when we pass to the more recondite phenomena of Physical Optics, Acoustics, and Electricity, it hardly needs the demonstrations which have involuntarily been given to show that the theoretical treatment must tend to degenerate into the pursuit of academic subtleties unless it is constantly vivified by direct contact with reality. Stokes, at all events, with little guidance or encouragement from his immediate environment, made himself from the first practically acquainted with the subjects he treated. Generations of Cambridge students recall the enthusiasm which characterised his experimental demonstrations in Optics. These appealed to us all; but some of us, I am afraid, under the influence of the academic ideas of the time, thought it a little unnecessary to show practically that the height of the lecture-room could be measured by the barometer, or to verify the calculated period of oscillation of water in a tank by actually timing the waves with the help of the image of a candle-flame reflected at the surface.

The practical character of the mathematical work of Stokes and his followers is shown especially in the constant effort to reduce the solution of a physical problem to a quantitative form. A conspicuous instance is furnished by the labour and skill which he devoted, from this point of view, to the theory of the Bessel's Function, which presents itself so frequently in important questions of Optics, Electricity, and Acoustics, but is so refractory to ordinary methods of treatment. It is now generally accepted that an analytical solution of a physical question, however elegant it may be made to appear by means of a judicious notation, is not complete so long as the results are given merely in terms of functions defined by infinite series or definite integrals, and cannot be exhibited in a numerical or graphical form. This view did not originate, of course, with Stokes; it is clearly indicated, for instance, in the works of Fourier and Poinsot, but no previous writer had, I think, acted upon it so consistently and thoroughly.

We have had so many striking examples of the fruitfulness of the combination of great mathematical and experimental powers that the question may well be raised, whether there is any longer a reason for maintaining in our minds a distinction between mathematical and experimental physics, or at all events whether these should be looked upon as separate provinces which may conveniently be assigned to different sets of labourers. It may be held that the highest physical research will demand in the future the possession of both kinds of faculty. We must be careful, however, how we erect barriers which would exclude a Lagrange on the one side or a Faraday on the other. There are many mansions in the palace of physical science, and work for various types of mind. A zealous, or over-zealous, mathematician might indeed make out something of a case if he were to contend that, after all, the greatest work of such men as Stokes, Kirchhoff, and Maxwell was mathematical rather than experimental in its complexion. An argument which asks us to leave out of account such things as the investigation of Fluorescence, the discovery of Spectrum Analysis, and the measurement of the Viscosity of Gases, may well seem audacious; but a survey of the collected works of these writers will show how much, of the very highest quality and import, would remain. However this may be, the essential point, which cannot, I think, be contested, is this, that if these men had been condemned and restricted to a mere book knowledge of the subjects which they have treated with such marvellous analytical ability, the very soul of their work would have been taken away. I have ventured to dwell upon this point because, although I am myself disposed to plead for the continued recognition of mathematical physics as a fairly separate field, I feel strongly that the traditional kind of education given to our professed mathematical students does not tend to its most effectual cultivation. This education is apt to be one-sided, and too much divorced from the study of tangible

things. Even the student whose tastes lie mainly in the direction of pure mathematics would profit, I think, by a wider scientific training. A long list of instances might be given to show that the most fruitful ideas in pure mathematics have been suggested by the study of physical problems. In the words of Fourier, who did so much to fulfil his own saying, 'L'étude approfondie de la nature est la source la plus féconde des découvertes mathématiques. Non-seulement cette étude, en offrant aux recherches un but déterminé, a l'avantage d'exclure les questions vagues et les calculs sans issue; elle est encore un moyen assuré de former l'analyse elle-même, et d'en découvrir les éléments qu'il nous importe le plus de connaître, et que cette science doit toujours conserver: ces éléments fondamentaux sont ceux qui se reproduisent dans tous les effets naturels.'

Another characteristic of the past century of applied mathematics is that it was, on the whole, the age of linear equations. The analytical armoury fashioned by Lagrange, Poisson, Fourier, and others, though subject, of course, to continual improvement and development, has served the turn of a long line of successors. The predominance of linear equations, in most of the physical subjects referred to, rests on the fact that the changes are treated as infinitely small. The theory of small oscillations, in particular, runs as a thread through a great part of the literature of the period in question. It has suggested many important analytical results, and still gives the best and simplest intuitive foundation for a whole class of theorems which are otherwise hard to comprehend in their various relations, such as Fourier's theorem, Laplace's expansion, Bessel's functions, and the like. Moreover, the interest of the subject, whether mathematical or physical, is not yet exhausted; many important problems in Optics and Acoustics, for example, still await solution. The general theory has in comparatively recent times received an unexpected extension (to the case of 'latent motions') at the hands of Lord Kelvin; and Lord Rayleigh, by his continual additions to it, shows that, in his view, it is still incomplete.

When the restriction to infinitely small motions is abandoned, the problems become of course much more arduous. The whole theory, for instance, of the normal modes of vibration which is so important in Acoustics, and even in Music, disappears. The researches hitherto made in this direction have, moreover, encountered difficulties of a less patent character. It is conceivable that the modern analytical methods which have been developed in Astronomy may have an application to these questions. It would appear that there is an opening here for the mathematician; at all events, the numerical or graphical solution of any one of the numerous problems that could be suggested would be of the highest interest. One problem of the kind is already classical—the theory of steep water-waves discussed by Stokes; but even here the point of view has perhaps been rather artificially restricted. The question proposed by him, the determination of the possible form of waves of permanent type, like the problem of periodic orbits in Astronomy, is very interesting mathematically, and forms a natural starting-point for investigation; but it does not exhaust what is most important for us to know in the matter. Observation may suggest the existence of such waves as a fact; but no reason has been given, so far as I know, why free water-waves should tend to assume a form consistent with permanence, or be influenced in their progress by considerations of geometrical simplicity.

I have tried to indicate the kind of continuity of subject-matter, method, and spirit which runs through the work of the whole school of mathematical physicists of which Stokes may be taken as the representative. It is no less interesting, I think, to examine the points of contrast with more recent tendencies. These relate not so much to subject-matter and method as to the general mental attitude towards the problems of Nature. Mathematical and physical science have become markedly introspective. The investigators of the classical school, as it may perhaps be styled, were animated by a simple and vigorous faith; they sought as a matter of course for a mechanical explanation of phenomena, and had no misgivings as to the trustiness of the analytical weapons which they wielded. But now the physicist and the mathematician alike are in trouble about their souls. We have discussions on the principles of mechanics, on the founda-

tions of geometry, on the logic of the most rudimentary arithmetical processes, as well as of the more artificial operations of the Calculus. These discussions are legitimate and inevitable, and have led to some results which are now widely accepted. Although they were carried on to a great extent independently, the questions involved will, I think, be found to be ultimately very closely connected. Their common nexus is, perhaps, to be traced in the physiological ideas of which Helmholtz was the most conspicuous exponent. To many minds such discussions are repellent, in that they seem to venture on the uncertain ground of philosophy. But, as a matter of fact, the current views on these subjects have been arrived at by men who have gone to work in their own way, often in entire ignorance of what philosophers have thought on such subjects. It may be maintained, indeed, that the mathematician or the physicist, as such, has no special concern with philosophy, any more than the engineer or the geographer. Nor, although this is a matter for their own judgment, would it appear that philosophers have very much to gain by a special study of the methods of mathematical or physical reasoning, since the problems with which they are chiefly concerned are presented to them in a much less artificial form in the circumstances of ordinary life. As regards the present topic I would put the matter in this way, that between Mathematics and Physics on the one hand and Philosophy on the other there lies an undefined borderland, and that the mathematician has been engaged in setting things in order, as he is entitled to do, on his own side of the boundary.

From this point of view, it would be of interest to trace in detail the relationships of the three currents of speculation which have been referred to. At one time I was tempted to take this as the subject of my Address; but, although I still think the enterprise a possible one, I have been forced to recognise that it demands a better equipment than I can pretend to. I can only venture to put before you some of my tangled thoughts on the matter, trusting that some future occupant of this Chair may be induced to take up the question and treat it in a more illuminating manner.

If we look back for a moment to the views currently entertained not so very long ago by mathematicians and physicists, we shall find, I think, that the prevalent conception of the world was that it was constructed on some sort of absolute geometrical plan, and that the changes in it proceeded according to precise laws; that, although the principles of mechanics might be imperfectly stated in our text-books, at all events such principles existed, and were ascertainable, and, when properly formulated, would possess the definiteness and precision which were held to characterise, say, the postulates of Euclid. Some writers have maintained, indeed, that the principles in question were finally laid down by Newton, and have occasionally used language which suggests that any fuller understanding of them was a mere matter of interpretation of the text. But, as Hertz has remarked, most of the great writers on Dynamics betray, involuntarily, a certain *malaise* when explaining the principles, and hurry over this part of their task as quickly as is consistent with dignity. They are not really at their ease until, having established their equations somehow, they can proceed to build securely on these. This has led some people to the view that the laws of Nature are merely a system of differential equations; it may be remarked in passing that this is very much the position in which we actually stand in some of the more recent theories of Electricity. As regards Dynamics, when once the critical movement had set in, it was easy to show that one presentation after another was logically defective and confused; and no satisfactory standpoint was reached until it was recognised that in the classical Dynamics we do not deal immediately with real bodies at all, but with certain conventional and highly idealised representations of them, which we combine according to arbitrary rules, in the hope that if these rules be judiciously framed the varying combinations will image to us what is of most interest in some of the simpler and more important phenomena. The changed point of view is often associated with the publication of Kirchhoff's lectures on Mechanics in 1876, where it is laid down in the opening sentence that the problem of Mechanics is to describe the motions which occur in Nature completely and in the simplest manner. This statement must not be taken too literally; at all

events, a fuller, and I think a clearer, account of the province and the method of Abstract Dynamics is given in a review of the second edition of Thomson and Tait, which was one of the last things penned by Maxwell, in 1879.[1] A 'complete' description of even the simplest natural phenomenon is an obvious impossibility; and, were it possible, it would be uninteresting as well as useless, for it would take an incalculable time to peruse. Some process of selection and idealisation is inevitable if we are to gain any intelligent comprehension of events. Thus, in Astronomy we replace a planet by a so-called material particle—*i.e.*, a mathematical point associated with a suitable numerical coefficient. All the properties of the body are here ignored except those of position and mass, in which alone we are at the moment interested. The whole course of physical science and the language in which its results are expressed have been largely determined by the fact that the ideal images of Geometry were already at hand at its service. The ideal representations have the advantage that, unlike the real objects, definite and accurate statements can be made about them. Thus two lines in a geometrical figure can be pronounced to be equal or unequal, and the statement is in either case absolute. It is no doubt hard to divest oneself entirely of the notion conveyed in the phrase ἀεὶ ὁ θεὸς γεωμετρεῖ, that definite geometrical magnitudes and relations are at the back of phenomena. It is recognised indeed that all our measurements are necessarily to some degree uncertain, but this is usually attributed to our own limitations and those of our instruments rather than to the ultimate vagueness of the entity which it is sought to measure. Everyone will grant, however, that the distance between two clouds, for instance, is not a definable magnitude; and the distance of the earth from the sun, and even the length of a wave of light, are in precisely the same case. The notion in question is a convenient fiction, and is a striking testimony to the ascendency which Greek Mathematics have gained over our minds, but I do not think that more can be said for it. It is, at any rate, not verified by the experience of those who actually undertake physical measurements. The more refined the means employed, the more vague and elusive does the supposed magnitude become; the judgment flickers and wavers, until at last in a sort of despair *some* result is put down, not in the belief that it is exact, but with the feeling that it is the best we can make of the matter. A practical measurement is in fact a classification; we assign a magnitude to a certain category, which may be narrowly limited, but which has in any case a certain breadth.

By a frank process of idealisation a logical system of Abstract Dynamics can doubtless be built up, on the lines sketched by Maxwell in the passage referred to. Such difficulties as remain are handed over to Geometry. But we cannot stop in this position; we are constrained to examine the nature and the origin of the conceptions of Geometry itself. By many of us, I imagine, the first suggestion that these conceptions are to be traced to an empirical source was received with something of indignation and scorn; it was an outrage on the science which we had been led to look upon as divine. Most of us have, however, been forced at length to acquiesce in the view that Geometry, like Mechanics, is an applied science that it gives us merely an ingenious and convenient symbolic representation of the relations of actual bodies; and that, whatever may be the *à priori* forms of intuition, the science as we have it could never have been developed except for the accident (if I may so term it) that we live in a world in which rigid or approximately rigid bodies are conspicuous objects. On this view the most refined geometrical demonstration can be resolved into a series of imagined experiments performed with such bodies, or rather with their conventional representations.

It is to be lamented that one of the most interesting chapters in the history of science is a blank; I mean that which would have unfolded the rise and growth of our system of ideal Geometry. The finished edifice is before us, but the record of the efforts by which the various stones were fitted into their places is hopelessly lost. The few fragments of professed history which we possess were edited long after the achievement.

[1] *Nature*, vol. xx. p. 213; *Scientific Papers*, vol. ii. p. 776.

It is commonly reckoned that the first rude beginnings of Geometry date from the Egyptians. I am inclined to think that in one sense the matter is to be placed much further back, and that the dawn of geometric ideas is to be traced among the prehistoric races who carved rough but thoroughly artistic outlines of animals on their weapons. I do not know whether the matter has attracted serious speculation, but I have myself been led to wonder how men first arrived at the notion of an outline drawing. The primitive sketches referred to immediately convey to the experienced mind the idea of a reindeer or the like; but in reality the representation is purely conventional, and is expressed in a language which has to be learned. For nothing could be more unlike the actual reindeer than the few scratches drawn on the surface of a bone; and it is of course familiar to ourselves that it is only after a time, and by an insensible process of education, that very young children come to understand the meaning of an outline. Whoever he was, the man who first projected the world into two dimensions, and proceeded to fence off that part of it which was reindeer from that which was not, was certainly under the influence of a geometrical idea, and had his feet in the path which was to culminate in the refined idealisations of the Greeks. As to the manner in which these latter were developed, the only indication of tradition is that some propositions were arrived at first in a more empirical or intuitional, and afterwards in a more intellectual way. So long as points had size, lines had breadth, and surfaces thickness, there could be no question of exact relations between the various elements of a figure, any more than is the case with the realities which they represent. But the Greek mind loved definiteness, and discovered that if we agree to speak of lines *as if* they had no breadth, and so on, exact statements became possible. If any one scientific invention can claim preeminence over all others, I should be inclined myself to erect a monument to the unknown inventor of the mathematical point, as the supreme type of that process of abstraction which has been a necessary condition of scientific work from the very beginning.

It is possible, however, to uphold the importance of the part which Abstract Geometry has played, and must still play, in the evolution of scientific conceptions, without committing ourselves to a defence, on all points, of the traditional presentment. The consistency and completeness of the usual system of definitions, axioms, and postulates has often been questioned; and quite recently a more thorough-going analysis of the logical elements of the subject than has ever before been attempted has been made by Hilbert. The matter is a subtle one, and a general agreement on such points is as yet hardly possible. The basis for such an agreement may perhaps ultimately be found in a more explicit recognition of the empirical source of the fundamental conceptions. This would tend, at all events, to mitigate the rigour of the demands which are sometimes made for logical perfection.

Even more important in some respects are the questions which have arisen in connection with the applications of Geometry to purposes of graphical representation. It is not necessary to dwell on the great assistance which this method has rendered in such subjects as Physics and Engineering. The pure mathematician, for his part, will freely testify to the influence which it has exercised in the development of most branches of Analysis; for example, we owe to it all the leading ideas of the Calculus. Modern analysts have discovered, however, that Geometry may be a snare as well as a guide. In the mere act of drawing a curve to represent an analytical function we make unconsciously a host of assumptions which are difficult not merely to prove, but even to formulate precisely. It is now sought to establish the whole fabric of mathematical analysis on a strictly arithmetical basis. To those who were trained in an earlier school, the results so far are in appearance somewhat forbidding. If the shade of one of the great analysts of a century ago could revisit the glimpses of the moon, his feelings would, I think, be akin to those of the traveller to some mediæval town, who finds the buildings he came to see obscured by scaffolding, and is told that the ancient monuments are all in process of repair. It is to be hoped that a good deal of this obstruction is only temporary, that most of the scaffolding will eventually be cleared away, and

that the edifices when they reappear will not be entirely transformed, but will still retain something of their historic outlines. It would be contrary to the spirit of this Address to undervalue in any way the critical examination and revision of principles; we must acknowledge that it tends ultimately to simplification, to the clearing up of issues, and the reconciliation of apparent contradictions. But it would be a misfortune if this process were to absorb too large a share of the attention of mathematicians, or were allowed to set too high a standard of logical completeness. In this particular matter of the 'arithmetisation of Mathematics' there is, I think, a danger in these respects. As regards the latter point, a traveller who refuses to pass over a bridge until he has personally tested the soundness of every part of it is not likely to go very far; something must be risked, even in Mathematics. It is notorious that even in this realm of 'exact' thought discovery has often been in advance of strict logic, as in the theory of imaginaries, for example, and in the whole province of analysis of which Fourier's theorem is the type. And it might even be claimed that the services which Geometry has rendered to other sciences have been almost as great in virtue of the questions which it implicitly begs as of those which it resolves.

I would venture, with some trepidation, to go one step further. Mathematicians love to build on as definite a foundation as possible, and from this point of view the notion of the integral number, on which (we are told) the Mathematics of the future are to be based, is very attractive. But, as an instrument for the study of Nature, is it really more fundamental than the geometrical notions which it is to supersede? The accounts of primitive peoples would seem to show that, in the generality which is a necessary condition for this purpose, it is in no less degree artificial and acquired. Moreover, does not the act of enumeration, as applied to actual things, involve the same process of selection and idealisation which we have already met with in other cases? As an illustration, suppose we were to try to count the number of drops of water in a cloud. I am not thinking of the mere practical difficulties of enumeration, or even of the more pertinent fact that it is hard to say where the cloud begins or ends. Waiving these points, it is obvious that there must be transitional stages between a more or less dense group of molecules and a drop, and in the case of some of these aggregates it would only be by an arbitrary exercise of judgment that they would be assigned to one category rather than to the other. In whatever form we meet with it, the very notion of counting involves the highly artificial conception of a number of objects which for some purposes are treated as absolutely alike, whilst yet they can be distinguished.

The net result of the preceding survey is that the systems of Geometry, of Mechanics, and even of Arithmetic, on which we base our study of Nature, are all contrivances of the same general kind: they consist of series of abstractions and conventions devised to represent, or rather to symbolise, what is most interesting and most accessible to us in the world of phenomena. And the progress of science consists in a great measure in the improvement, the development, and the simplification of these artificial conceptions, so that their scope may be wider and the representation more complete. The best in this kind are but shadows, but we may continually do something to amend them.

As compared with the older view, the function of physical science is seen to be much more modest than was at one time supposed. We no longer hope by levers and screws to pluck out the heart of the mystery of the universe. But there are compensations. The conception of the physical world as a mechanism, constructed on a rigid mathematical plan, whose most intimate details might possibly some day be guessed, was, I think, somewhat depressing. We have been led to recognise that the formal and mathematical element is of our own introduction; that it is merely the apparatus by which we map out our knowledge, and has no more objective reality than the circles of latitude and longitude on the sun. A distinguished writer not very long ago speculated on the possibility of the scientific mine being worked out within no distant period. Recent discoveries seem to have put back this possibility indefinitely; and the tendency of modern speculation as to the nature of scientific knowledge should be to banish

it altogether. The world remains a more wonderful place than ever; we may be sure that it abounds in riches not yet dreamed of; and, although we cannot hope ever to explore its innermost recesses, we may be confident that it will supply tasks in abundance for the scientific mind for ages to come.

One significant result of the modern tendency is that we no longer with the same obstinacy demand a mechanical explanation of the phenomena of Light and Electricity, especially since it has been made clear that if one mechanical explanation is possible, there will be an infinity of others. Some minds, indeed, revelling in their new-found freedom, have attempted to disestablish ordinary or 'vulgar' matter altogether. I may refer to a certain treatise which, by some accident, does not bear its proper title of 'Æther and *no* Matter,' and to the elaborate investigations of Professor Osborne Reynolds, which present the same peculiarity, although the basis is different. Speculations of this nature have, however, been so recently and (if I may say it) so brilliantly dealt with by Professor Poynting before this Section that there is little excuse for dwelling further on them now. I will only advert to the question whether, as some suggest, physical science should definitely abandon the attempt to construct mechanical theories in the older sense. The question would appear to be very similar to this, whether we should abandon the use of graphical methods in analysis? In either csae we run the risk of introducing extraneous elements, possibly of a misleading character; but the gain in vividness of perception and in suggestiveness is so great that we are not likely to forego it, by excess of prudence, in one case more than in the other.

We have travelled some distance from Stokes and the mathematical physics of half a century ago. May I add a few observations which might perhaps have claimed his sympathy? They are in substance anything but new, although I do not find them easy to express. We have most of us frankly adopted the empirical attitude in physical science; it has justified itself abundantly in the past, and has more and more forced itself upon us. We have given up the notion of causation, except as a convenient phrase; what were once called laws of Nature are now simply rules by which we can tell more or less accurately what will be the consequences of a given state of things. We cannot help asking, How is it that such rules are possible? A rule is invented in the first instance to sum up in a compact form a number of past experiences; but we apply it with little hesitation, and generally with success, to the prediction of new and sometimes strange ones. Thus the law of gravitation indicates the existence of Neptune; and Fresnel's wave-surface gives us the quite unsuspected phenomenon of conical refraction. Why does Nature make a point of honouring our cheques in this manner; or, to put the matter in a more dignified form, how comes it that, in the words of Schiller,[1]

> 'Mit dem Genius steht die Natur im ewigen Bunde,
> Was der eine verspricht, leistet die andre gewiss'?

The question is as old as science, and the modern tendencies with which we have been occupied have only added point to it. It is plain that physical science as such has no answer; its policy indeed has been to retreat from a territory which it could not securely occupy. We are told in some quarters that it is vain to look for an answer anywhere. But the mind of man is not wholly given over to physical science, and will not be content for ever to leave the question alone. It will persist in its obstinate questionings, and, however hopeless the attempt to unravel the mystery may be deemed, physical science, powerless to assist, has no right to condemn it.

I would like, in conclusion, to read to you a characteristic passage from that Address of Stokes in 1862 which has formed the starting-point of this discourse:—

'In this Section, more perhaps than in any other, we have frequently to deal with subjects of a very abstract character, which in many cases can be mastered

[1] Applied by Sir J. Herschel to the discovery of Neptune.

only by patient study, at leisure, of what has been written. The question may not unnaturally be asked, If investigations of this kind can best be followed by quiet study in one's own room, what is the use of bringing them forward in a Sectional meeting at all? I believe that good may be done by public mention, in a meeting like the present, of even somewhat abstract investigations; but whether good is thus done, or the audience merely wearied to no purpose, depends upon the judiciousness of the person by whom the investigation is brought forward.'

It might be urged that these remarks are as pertinent now as they were forty years ago, but I will leave them on their own weighty authority. I will not myself venture to emphasise them, lest some of my hearers should be tempted to retort that the warning might well be borne in mind, not only in the ordinary proceedings of the Section, but in the composition of a Presidential Address!

The following Papers were read:—

1. *Thermal Dilatation of Compressed Hydrogen.* *By* A. W. Witkowski.

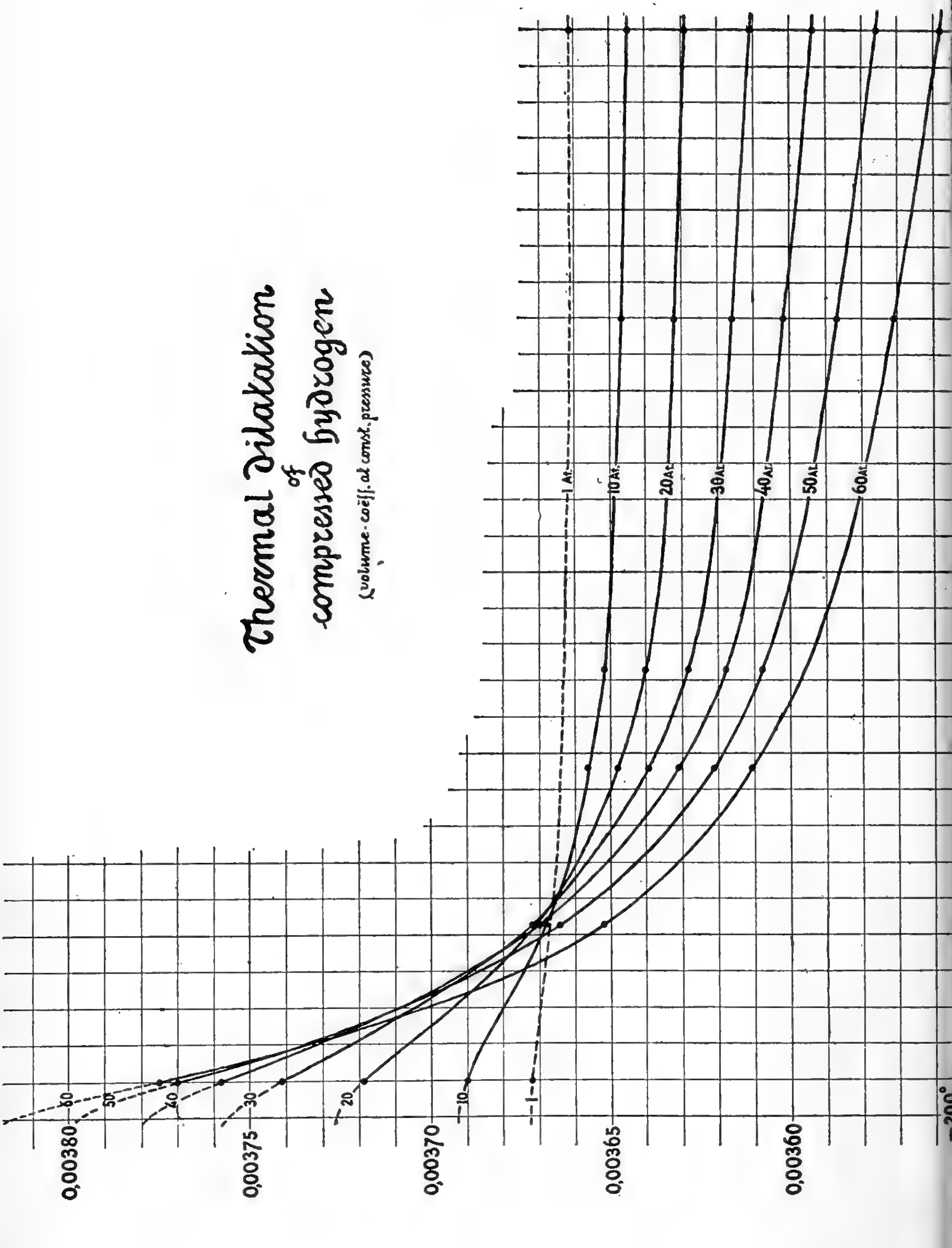
The experiments of which the results are quoted below were undertaken with the view of obtaining data necessary for the construction of isothermals of hydrogen, down to the lowest available temperatures. The immediate object of these determinations was the volume-coefficient of dilatation a, as depending on pressure and temperature, a being defined by the equation $v = v_0 (1 + a\theta)$, in which v_0 and v denote the volumes of any quantity of hydrogen, measured both under a constant pressure of p atmospheres, at the temperature of melting ice, and θ (Centigrade, constant volume, hydrogen scale) degrees respectively. The method of experimenting was similar in principle to that used in the author's previous researches on atmospheric air.[1] A summary of the most reliable results, as far as they go up to now, is contained in the following table, illustrated by the annexed diagram.

Pressure atmos.	Temperature θ					
	+100°	+20°	−77°	−104°	−147°	−190°
	Values of $10^5 \times a$.					
1	366·1[1]	—	—	—	—	367·2[2]
10	364·6	364·7	365·2	365·6	366·8	369·0
20	362·9	363·2	364·0	364·9	367·1	371·9
30	361·1	361·6	362·9	364·0	367·2	374·1
40	359·4	360·2	361·8	363·1	367·0	375·8
50	357·6	358·7	360·8	362·1	366·4	377·0
60	355 8	357·1	—	361·1	365·2	377·5

[1] Régnault.
[2] Travers and Senter (*Brit. Assoc. Rep.* 1901).

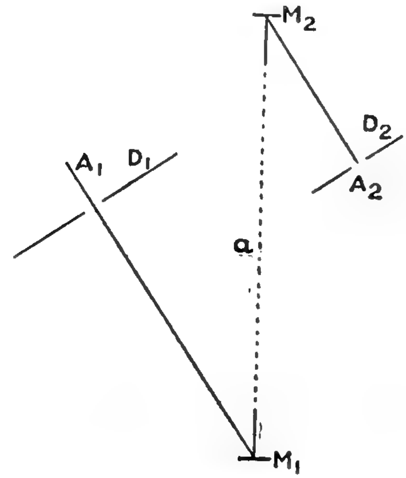
The last figure is expected to be uncertain, probably by less than five units.

[1] *Cracow Acad. Rozprawy*, vol. xxiii. 1891.


Thermal dilatation of compressed hydrogen
(volume-coeff. at const. pressure)
1 At.
10 At.
20 At.
30 At.
40 At.
50 At.
60 At.
60
50
40
30
20
10
1
0,00380
0,00375
0,00370
0,00365
0,00360
-200°

2. *Experiments to decide whether the Ether moves with the Earth. By* Professor W. Wien.

In the theory of electro-dynamics, founded by H. A. Lorentz on the hypothesis of electrons, the questions as to a possible influence of the earth's motion on optic and electric phenomena are of the greatest importance. A short time ago, it seemed dubious whether the theory was able to overcome the difficulties of the negative result of the well-known experiments of Michelson and Morley, Lord Rayleigh, Brare, Trouton, and Noble. But the recent assumption of Lorentz that the electrons have the form of an ellipsoid, the relation of the axes being dependent upon the velocity—Mr. Searle has called such ellipsoids Heaviside ellipsoids—leads to the conclusion that all optical experiments in which a part of the system is made dark by interference or rotation of the plane of polarisation should give a negative result. One must of course make the hypothesis that all forces and all masses follow the general electro-magnetic laws, and that we have to consider only electro-magnetic phenomena. I myself[1] pronounced the opinion some years ago that it may be of the utmost consequence to found mechanics, too, on the general equations of the electro-magnetic field, and to define the mass as the



electro-magnetic mass of the charged Heaviside ellipsoids, regarded as the constituents of all material bodies.

Taking this point of view, it seems to me that no results could be expected from the experiments with the rotation of the plane of polarisation of light, from which the earlier theory of Lorentz led us to expect an influence of the earth's motion of the first order. On the other hand, I found that the common theory of dispersion gives a positive result of the Michelson-Morley experiment if the rays go through water instead of air. This result cannot be annulled by the FitzGerald-Lorentz contraction hypothesis. But the recent theory of Lorentz expects a negative result in this case too, and I must confess that I have no further hope that we should find anything of a positive effect from those optical or electrical observations.

But from one experiment it seems to me that, independent of all theory, a positive result should be expected if the ether does not move at all with the earth. The experiment lies exactly on the limit that by extreme accuracy could be observed, and I do not know whether it is possible or not with our present means of observation.

If we measure the velocity of light, using Fourault's method, but in such a manner that the ray of light does not go back along the same path, we should

[1] And Prof. Larmor has had the same idea.

find a difference in the velocity of light according to whether we make the ray go in the same direction as the earth or in the opposite.

Such a measurement of the velocity of light would be only possible when we use two mirrors at a great distance from each other which rotate with the same angular velocity.

Let A_1 be a source of light going through a diaphragm D and falling on the mirror M_1, whence it is reflected to the second mirror M_2. The ray goes after reflection from this mirror to D_2. Another ray coming from the source A_2 takes the same path, and, since both mirrors remain at rest, comes to A_1. But if the mirrors rotate in the same phase the ray requires time to traverse the long distance a and finds the mirror M_1 in a changed position, so that the ray does not come to A_1, but makes an angle with the direction $M_1 A_1$. The observation of this angle gives us the velocity of light as it is well known in Fourault's method. Reversely the ray coming from A_1 will not go to A_2, but makes an angle with the direction M_2A_2, depending also upon the velocity of light.

But both the values of this velocity could not be the same if the earth moves in the direction $M_1 M_2$.

For in the time that the light needs to go from M_1 to M_2, the mirror M_2 has changed its place and increased the distance from a to $a+x$. Let c be the velocity of light, v that of earth, then we have

$$\frac{a+x}{c}=\frac{x}{v}; \quad \text{or} \quad x=\frac{av}{c-v}.$$

The time of the ray between M_1 and M_2 is therefore $\frac{a}{c-v}$, and for the opposite ray between M_2 and M_1 $\frac{a}{c+v}$. Thus we should find a difference in the time which the two rays need to travel over the distance a in the amount of $2\frac{v}{c}$ of the value, that is $\frac{1}{5000}$.

It seems that the best observations of the velocity of light have obtained a greater accuracy than we need here But we ought to remember that the difficulties of these proposed experiments are far greater, because the mirrors M_1 and M_2 have to rotate with the same velocity. On the other hand, this agreement has to last only a short time, and every difference of the angular velocity could be detected by a change in the direction of the ray. That is the reason why I hope the difficulties may be overcome, like many others, by the experience of a physicist like Mr. Michelson, and I am glad to draw attention to this problem.

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3. *Preliminary Note on the Tangential Stress due to Light incident obliquely on an Absorbing Surface. By* Professor J. H. POYNTING, *D.Sc., F.R.S.*

The existence of pressure on a surface, due to the incidence of a normal beam of light, first deduced as a consequence of the electromagnetic theory by Maxwell, has been fully confirmed by the experiments of Lebedew, and quite independently by the exact work of Nichols and Hull. These experiments show that the pressure exists, and that it is equal to the energy per c.c., or to the energy density in the incident beam.

In so far as it produces this pressure, we may regard the beam as a stream of momentum, the direction of the momentum being along the line of propagation, and the amount of momentum passing per second through unit area cross section of the beam being equal to the density of the energy in it. Let E denote this energy density. If the beam is inclined at θ to the normal to a surface on which it falls, the momentum stream on to unit area of the surface is $E\cos\theta$ per second, and this is the force which the beam will exert in its own direction. If the beam is entirely absorbed, the result is a pressure $E\cos^2\theta$ along the normal, and a

tangential stress on the plane of incidence $E \sin\theta\cos\theta = \frac{1}{2}E\sin 2\theta$. If μ of the incident beam is reflected, the normal pressure is $(1+\mu)E\cos^2\theta$ and the tangential stress is $\frac{1-\mu}{2}E\sin 2\theta$.[1] When there is absorption, the tangential stress has a maximum value at 45° if μ is constant. When there is no absorption the tangential stress disappears.

The tangential stress is much more easily detected than the normal pressure, for the action of the gas surrounding the surface is normal to it, and is with difficulty disentangled from the normal light pressure. But the gas action is at right angles to the tangential stress, and it is merely necessary to arrange a surface, free to move in its own plane, to eliminate the action of the normal forces and to reveal the tangential stress.

With the assistance of my colleague, Dr. Guy Barlow, to whom I am much indebted for help in the work, I have made the following experiment to show the existence of the stress.

Two circular glass discs, each 2·75 sq. cm. area, were fixed at the ends of a horizontal light glass rod 5 cm. long, the discs being *perpendicular* to the rod and fixed to it at their highest points. One of the discs was lampblacked and the other silvered. The rod was placed in a light wire cradle and suspended by a fine quartz fibre about 25 cm. long in a brass case with glazed sides. On the cradle was a mirror, by which deflections could be observed with a telescope on a millimetre scale 1·8 metres distant. The moment of inertia of the system was 2·35 gm. cm^2, and the time of vibration was 146 seconds. A deflection of 1 scale division therefore corresponded to a tangential force on a disc of about one two-millionth of a degree—more exactly $·483 \times 10^{-6}$.

The air was pumped from the case till the pressure was less than 1 cm. of mercury. At this pressure the irregularity of the disturbances, due to the residual gas, is very greatly reduced. A parallel beam of light from a Nernst lamp was then directed so as to be incident obliquely on the lampblacked disc. From the arrangement of the discs it is obvious that a uniformly distributed normal force would have no moment tending to twist the system, while a tangential force would have a moment and would twist it. In all cases the disc moved away from the source of light. The deflection was a maximum when the incidence was not very far from 45° and fell off on each side of the maximum value. As there are various sources of error not yet removed, we have not made a complete series of measurements, but have only made sure that the effect is of the order to be expected from the theory, by finding the deflection for an angle of 45°.

The beam from the Nernst lamp, when incident at 45°, turned the rod through 16·5 scale divisions. Assuming total absorption, the tangential force should be $\frac{1}{2}E\sin 2\theta \times$ area of disc $= \frac{1}{2}E \times 2·75$.

Equating to the value of the force given by the deflection, viz. $0·483 \times 10^{-6} \times 16·5$, we have $E = 5·8 \times 10^{-6}$.

The same beam was then directed on to a small lampblacked silver disc of known heat capacity, through a glass plate of thickness equal to that of the side of the case. The initial rise of temperature per second was measured by a thermo-junction of constantan wire soldered to the disc. The energy density of the stream was thus found to be $E = 6·5 \times 10^{-6}$.

The agreement of the two values is quite as close as could be expected in so rough a determination.

When the beam was directed on to the silver disc at the other end of the torsion rod the deflection was much less, as was to be expected.

We have also made some qualitative experiments with a blackened glass cylinder—a ring cut from a test tube—suspended by a quartz fibre with its axes vertical. When a beam fell on this in any direction, not along a diameter, there was always a twist in the direction corresponding to the tangential stress.

[1] These expressions are given in 'Radiation in the Solar System,' *Phil. Trans.* A, vol. 202, p. 539.

4. *The Reaction of the Radiation on a Moving Electron.* *By* Professor M. ABRAHAM.

The moving electron gives rise to an electromagnetic field which exerts a force on the electron. For velocities small compared with the velocity of light, the expression for this force is

(1) $$\mathfrak{K}_i = \mathfrak{K}_i' + \mathfrak{K}_i'' + \ldots$$

where the first term

(2) $$\mathfrak{K}_i' = -\mu_0 \dot{\mathfrak{g}}$$

is equal to the vector of acceleration multiplied by the electromagnetic mass, the existence of which was first suggested by J. J. Thomson in 1881.

The second term

(3) $$\mathfrak{K}_i'' = \frac{2}{3}\frac{e^2}{c^3}\ddot{\mathfrak{g}} = b \cdot \ddot{\mathfrak{g}}$$

first given by H. A. Lorentz, is a dissipative force, coming from the reaction of the radiation.

Indeed, if you consider a motion of the electron, in which the vector velocity $\mathfrak{g}$ is constant up to the time t_1, and after the time t_2, but which has an acceleration during the interval $t_1 < t < t_2$, the work done during this interval by the force $\mathfrak{K}_i''$ is

$$\int_1^2 dt\, \mathfrak{g}\, \mathfrak{K}_i'' = b \int_1^2 dt\, \mathfrak{g}\, \ddot{\mathfrak{g}}.$$

As $\dot{\mathfrak{g}} = \sigma$ for t_1, t_2, integration by parts gives

(4) $$\int_1^2 dt\, \mathfrak{g}\, \mathfrak{K}_i'' = -b \int_1^2 dt\, \dot{\mathfrak{g}}^2 = -\mathrm{W}_{12},$$

where W_{12} is the energy, calculated by J. Larmor and others, which the waves formed during the interval $t_1 < t < t_2$ carry with them. Therefore $\mathfrak{K}_i''$ may be called the dissipative force exerted by the radiation on a slowly moving electron.

The electrons emitted by radio-active bodies are moving with very high velocities. The experiments of W. Kaufmann show that the β-rays of radium are negative electrons with velocities greater than two-thirds of the velocity of light, and, if F. Laschen is right, the so-called γ-rays contain electrons moving with nearly the velocity of light, and maybe the velocity of light itself is attained. The theory therefore must be extended to the general case of rapid motion, where $\frac{g}{c} = \beta$ is smaller than, but not small compared with 1.

As to the first term $\mathfrak{K}_i'$, I have previously given the general value

(5) $$\mathfrak{K}_i' = -\frac{d\mathfrak{G}}{dt},$$

where $\mathfrak{G}$ is the vector of the electromagnetic momentum which the electron carries with it. From this formula I get the general expression for the electromagnetic mass. The 'longitudinal mass,' corresponding to acceleration in the direction of motion, is

(6) $$\mu_s = \frac{d\,\mathrm{G}}{d\,g} \qquad \mathrm{G} = (\mathfrak{G}),$$

while the 'transverse mass' which comes into play in the case of deviation of β-rays is

(7) $$\mu_r = \frac{\mathrm{G}}{g}$$

For slow motion, in which the momentum is a linear function of the velocity, the two masses are equal, but in general they are different.

The value of the momentum depends of course on the shape of the electron. I will not discuss this matter in detail, because the second force of which I shall speak is independent of the shape and size of the electron. It is closely connected with the radiation of a point-change by the relations

$$(8) \qquad \int_1^2 dt\, \mathfrak{g}\, \mathfrak{K}_i'' = -W_{12},$$

$$(9) \qquad \int_1^2 dt\, \mathfrak{K}_i'' = -\mathfrak{G}_{12},$$

where W_{12}, $\mathfrak{G}_{12}$ are the radiated energy and the radiated momentum respectively. They are given by

$$(10) \qquad W_{12} = \frac{2}{3}\frac{e^2}{c^3}\int_1^2 dt \left\{ \frac{\dot{\mathfrak{g}}^2}{\kappa^4} + \frac{(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^2\kappa^6} \right\},$$

$$(11) \qquad W_{12} = \frac{2}{3}\frac{e^2}{c^3}\int_1^2 dt\, \frac{\mathfrak{g}}{c^2} \left\{ \frac{\dot{\mathfrak{g}}^2}{\kappa^4} + \frac{(\mathfrak{g}\,\dot{\mathfrak{g}}^2)}{c^2\kappa^6} \right\},$$

with $\kappa^2 = 1 - \beta^2$.

I gave these values in 'Annalen der Physik 10,' p. 156, 1903, the paper being sent in on October 23, 1902. The same formulæ have been found independently by O. Heaviside, 'Nature,' 6 T., p. 6, November 6, 1902.

Now the required force $\mathfrak{K}_i''$, substituted in (8) and (9), must give these values of W_{12}, $\mathfrak{G}_{12}$. We can show that with these conditions $\mathfrak{K}_i''$ is determined completely, if we take into consideration that the complete value $\mathfrak{K}_i$ of the reaction of the field can be regarded as an expansion in ascending powers of $\dot{\mathfrak{g}}$, $\ddot{\mathfrak{g}}$, . . ., and that the general value of $\mathfrak{K}_i''$ must be of the same dimensions as $b\,\ddot{\mathfrak{g}}$ without containing a power of the radius as factor. The most general expression of this sort is zero, if it gives zero both for radiated energy and radiated momentum. From this it follows that the proposed problem has only one solution.

This solution is

$$(12) \qquad \mathfrak{K}_i'' = \frac{2}{3}\frac{e^2}{c^3}\left\{ \frac{\ddot{\mathfrak{g}}}{\kappa^2} + \frac{\mathfrak{g}\,(\mathfrak{g}\,\ddot{\mathfrak{g}})}{c^2\kappa^4} + \frac{3\,\dot{\mathfrak{g}}\,(\mathfrak{g}\,\dot{\mathfrak{g}})}{c^2\kappa^4} + \frac{3\,\mathfrak{g}\,(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^4\kappa^6} \right\}.$$

Indeed, you get

$$\mathfrak{g}\,\mathfrak{K}_i'' = b\left\{ \frac{\mathfrak{g}\,\ddot{\mathfrak{g}}}{\kappa^4} + \frac{3\,(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^2\kappa^6} \right\},$$

and, because $\dot{\mathfrak{g}} = \sigma$ for t_1, t_2, integration by parts gives

$$\int_1^2 \frac{dt\,\mathfrak{g}\,\ddot{\mathfrak{g}}}{\kappa^4} = -\int_1^2 dt \left\{ \frac{\dot{\mathfrak{g}}^2}{\kappa^4} + \frac{4\,(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^2\kappa^6} \right\};$$

hence

$$\int_1^2 dt\,\mathfrak{g}\,\mathfrak{K}_i'' = -b\int_1^2 dt \left\{ \frac{\dot{\mathfrak{g}}^2}{\kappa^4} + \frac{(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^2\kappa^6} \right\},$$

in agreement with (10).

On the other hand, you get by integration by parts

$$\int_1^2 dt \left\{ \frac{\ddot{\mathfrak{g}}}{\kappa^2} + \frac{\mathfrak{g}\,(\mathfrak{g}\,\ddot{\mathfrak{g}})}{c^2\kappa^4} \right\} = \int_1^2 dt \left\{ \frac{\mathfrak{g}\,\dot{\mathfrak{g}}^2}{c^2\kappa^4} + \frac{3\,\dot{\mathfrak{g}}\,(\mathfrak{g}\,\dot{\mathfrak{g}})}{c^2\kappa^4} + \frac{4\,\mathfrak{g}\,(\mathfrak{g}\,\dot{\mathfrak{g}})^2}{c^2\kappa^6} \right\}.$$

Therefore the time integral of $\mathfrak{K}_i''$ is equal to $-\mathfrak{G}_{12}$.

Hence (12) is the general expression of the reaction of the radiation on a point-charge, moving with a velocity smaller than the velocity of light.

Consider some examples.

a. Uniform Motion along a Circle.—You have $\dot{\mathfrak{g}} \perp \mathfrak{g}$, $\ddot{\mathfrak{g}} = -\mathfrak{g}\frac{g^2}{r^2}$, r being the radius of the circle.

Equation (12) gives

$$\mathfrak{K}_i'' = -b\,\frac{\mathfrak{G}}{\kappa^4}\,\frac{g^2}{r^2}.$$

That is a frictional force opposite to the direction of motion. It is proportional to the square of the curvature of the path, or to the square of the intensity of the transverse magnetic field producing the circular motion. Near the velocity of light, when κ is very small, the force increases rapidly.

b. Uniform Motion along an Helix.—Put $\mathfrak{g} = \mathfrak{g}_1 + \mathfrak{g}_2$, where $\mathfrak{g}_1$ is the constant velocity along the axis of the screw, $\mathfrak{g}_2$ the projection of $\mathfrak{g}$ to a plane perpendicular to the axis. Let r be the radius of the circle, described with velocity $\mathfrak{g}_2$. Consider that $\dot{\mathfrak{g}} = \dot{\mathfrak{g}}_2$ is perpendicular both to $\mathfrak{g}_1$ and $\mathfrak{g}_2$, and that

$$\ddot{\mathfrak{g}} = \ddot{\mathfrak{g}}_2 = -\mathfrak{g}_2 \frac{g_2^2}{r^2},$$

you get

$$\mathfrak{g}\dot{\mathfrak{g}} = \sigma, \ \mathfrak{g}\ddot{\mathfrak{g}} = -\frac{g_2^4}{r^2};$$

hence

$$\mathfrak{K}_i'' = -b\left\{\frac{\mathfrak{g}_2}{\kappa^2}\frac{g_2^2}{r^2} + \frac{\mathfrak{g}}{c^2\kappa^4}\frac{g_2^4}{r^2}\right\}.$$

Putting

$$\frac{g_2}{c} = \beta_2, \ \frac{g_1}{c} = \beta_1, \ \beta_1^2 + \beta_2^2 = \beta^2,$$

you can write

$$\mathfrak{K}_i'' = -b\,\mathfrak{g}_1\frac{g_2^2\beta_2^2}{\kappa^4 r^2} - b\,\mathfrak{g}_2\frac{g_2^2(1-\beta_1^2)}{\kappa^4 r^2}.$$

The first term gives a force resisting the rectilinear motion $\mathfrak{g}_1$ along the axis of the helix, the second term a force resisting the circular motion $\mathfrak{g}_2$. When the electron moves rapidly through a homogeneous magnetic field both forces come into play.

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5. *Quantitative Determination of the Anomalous Dispersion of Sodium Vapour.*[1] *By* Professor R. W. Wood.

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6. *On the Dynamical Significance of Kundt's Law of Anomalous Dispersion. By* Professor J. Larmor, *Sec. R.S.*

It was pointed out that the energy of a train of approximately homogeneous radiation must be propagated forwards; on the principles of O. Reynolds and Rayleigh this requires that the group-velocity must be positive, provided there is no absorption. Thus, outside an absorption-band the index of refraction must always increase with increasing frequency of the wave-train. Inside the absorption-band the argument does not apply, but the curve of dispersion there bends round so as to connect the two arcs, both with upward trend, on the two sides of the band. These are the features of actual dispersion-curves to which Kundt drew attention.

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7. *On the Relation of the Röntgen Radiation to Ordinary Light. By* Professor J. Larmor, *Sec. R.S.*

Arguments were offered in support of the view advanced by Sir George Stokes ('Wilde Lecture,' Lit. and Phil. Soc., Manchester, 1897) that a single radiant pulse, incident on a molecular medium, would not suffer regular refraction. As natural radiation consists of a succession of pulses, propagated from molecular shocks occurring at the surface of the incandescent solid or liquid radiator, it becomes necessary on this view to specify some kind of regularity in the shocks, in order to explain refraction and dispersion. It is held that a statistical regu-

[1] Appeared in full in the *Phil. Mag.*, viii. p. 293.

larity, such as is connected in molecular theory (*e.g.* gas theory) by the existence at each point of a definite temperature, is adequate for this purpose. On the other hand, if the Röntgen rays consist of absolutely independent pulses, devoid of all regularity in their succession, thus comparable to the traffic along a street or to the fire of a skirmishing company of soldiers, they would undergo no regular refraction.

Department of Mathematics.

The following Papers were read :—

1. *A Fragment of Elementary Mathematics.* *By* Professor F. Morley.

The text-books of elementary analytical geometry are introductory to Projective Geometry. It is easy to work out an analytic introduction to Inversive Geometry, and such an introduction is, I have found, of much interest to students at an early stage, because it connects very directly with the class of facts handled in Euclid or his substitutes, or in such books as Casey's 'Sequel to Euclid,' and also because the algebra is transparent, the geometric operations being in evidence. And such an introduction is of value to students later on in the geometric side of the theory of functions of a complex number, and in vector analysis.

We work in a plane with reflexions in lines, two reflexions being a rotation. The operation of rotating may be called a turn (or ort, Heaviside), and denoted by t. A turn is thus a complex number of absolute value or length unity, but there is no necessity to speak of complex numbers. By itself, t may be thought of as a point on a base circle of unit radius. The centre of this circle is the base point or origin; a fixed line through the base point is the base line or axis of reals. The reflexion of a point x in the base line may be denoted by $\bar{x}$ or y as is convenient; this reflexion is the conjugate of x.

The map-equation of a line is

$$x=\frac{a}{1-t};$$

and forms of the conjugate equation of a line are

$$x/a+\bar{x}/\bar{a}=1,$$

$$x+t^2\bar{x}=\rho t.$$

It is important here to note that between a point x and its reflexion x_1 in this line we have the relation

$$x/a+\bar{x}_1/\bar{a}=1.$$

A similar remark applies to circles—namely, that the conjugate equation

$$x\bar{x}-a\bar{x}-\bar{a}x=\rho^2$$

is a special case of the relation $x\bar{x}_1-a\bar{x}_1-\bar{a}x=\rho^2$, which connects inverse points.

After adequate explanation of these preliminaries, we have next (1) the metrical theory of the n-lines, including in particular convenient proofs of the known metrical facts of the triangle; and (2) the theory of rational curves, such curves as, for example, the *limaçon type*:

$$x=\text{a polynomial in } t;$$

the *hyperbola type*:

$$x=\sum\frac{A_\iota}{t-t_\iota};$$

the *parabola type*:

$$a = \sum \frac{A_\iota}{(t - t)^2};$$

the curves given by

$$a_o t_n + a_1 t^{n-1} + \ . \ . \ . + a = 0,$$

where a_ι and $a_{n-\iota}$ are conjugate and one of these pairs varies with t.

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2. *Peano's Symbolic Method.* *By* A. N. Whitehead, *F.R.S.*

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3. *The Theory of Linear Partial Differential Equations.* *By* Major P. A. MacMahon, *Sc.D., F.R.S.*

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4. *On the Roots of the Characteristic Equation of a Linear Substitution.* *By* T. J. I'A. Bromwich.

The equation in λ,

$$\begin{vmatrix} a_{1,1}-\lambda, & a_{1,2}, & . \ . \ ., & a_{1,n} \\ a_{2,1}, & a_{2,2}-\lambda, & . \ . \ ., & a_{2,n} \\ . & . & . & . \\ a_{n,1}, & a_{n,2}, & . \ . \ ., & a_{n,n}-\lambda \end{vmatrix} = 0,$$

or, let us say briefly, $|a-\lambda| = 0$, has been much discussed. It is known that the roots are real if a is a symmetric matrix; pure imaginaries (or zero) if a is an alternate matrix; and that the absolute value of all the roots is unity in case a represents an orthogonal substitution.

If no information is available about special relations amongst the letters a, it is no longer possible to make such definite statements. The following theorem throws some light on the general case:—

Write $b_{r,s} = \frac{1}{2}(a_{r,s} + a_{s,r})$, $c_{r,s} = \frac{1}{2}(a_{r,s} - a_{s,r})$ so that the matrix b is symmetric and c is alternate; let the roots of $|b-\lambda| = 0$ be $\alpha_1, \alpha_2, \alpha_n$, where $\alpha_1 > \alpha_2 > \ . \ . \ . > \alpha_n$; and let the roots of $|c-\lambda| = 0$ be $\pm i\gamma_1, \pm i\gamma_2 \ . \ . \ ., \pm i\gamma_p$, where $\gamma_1 > \gamma_2 > \ . \ . \ . > \gamma_p > 0$. Then the real part of any root of $|a-\lambda| = 0$ lies between α_1 and α_n; and the absolute value of the imaginary part is not greater than γ_1.

The first part of this theorem is due to Bendixson;[1] the second seems to be new.

Hitherto all the letters $a_{r,s}$ have been taken to be *real*; if they are complex a modification of the theorem is necessary. Let the accented letter $a'_{r,s}$ represent the conjugate complex to $a_{r,s}$. Then write

$$b_{r,s} = \tfrac{1}{2}(a_{r,s} + a'_{s,r}), \quad ic_{r,s} = \tfrac{1}{2}(a_{r,s} - a'_{s,r}),$$

so that the matrices b, c have the property expressed by the equations

$$b'_{r,s} = b_{s,r}, \quad c'_{r,s} = c_{s,r}.$$

It is known that the two equations in λ,

$$|b-\lambda| = 0, \quad |c-\lambda| = 0,$$

have real roots in consequence of the property just stated: denote these roots by $\beta_1, \beta_2, \ . \ . \ ., \beta_n$ and $\gamma_1, \gamma_2, \ . \ . \ ., \gamma_n$ respectively, and suppose them again arranged in order of magnitude. *Then the equation $|a-\lambda| = 0$ has the property that the real*

[1] *Öfversigt af K. Vet. Akad. Förh. Stockholm*, 1900; *Acta Mathematica*, t. 25, 1902, p. 359.

part of any root lies between β_1 and β_n, and the absolute value of the imaginary part lies between γ_1 and γ_n.

The first part of this theorem is due to Hirsch,[1] but the second seems new.

I have attempted also to obtain some connection between the invariant factors of the determinant $a-\lambda$ and those of[2] $b-\lambda c$, but hitherto without success. I have constructed, however, certain examples which show that the connection (if there is one) cannot be obtained by any very simple method.

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5. *On the Zeroes of Two Classes of Taylor Series.* *By* G. H. Hardy.

The problem of obtaining reasonably precise information as to the nature of the zeroes of an integral function defined by a Taylor series is one which may fairly be said to be generally impracticable, at any rate with the analytical machinery at present at our disposal. The utmost which has been accomplished in this direction is the determination of certain limits for the increase (*croissance*) of the moduli of the zeroes when corresponding limits for the increase of the coefficients are given, these limits being found by the determination, as a preliminary step, of limits for the increase of the function itself. For this reason it seems to me that the results proved in this paper may be of interest to those who are engaged in the study of the general theory of integral functions. They are essentially results concerning particular cases, but they are very much more precise than any results so far furnished by any of the general theorems.

Of the two classes of functions dealt with, the second is perhaps the more interesting in itself. On the other hand, the determination of the zeroes of the first class seems of more theoretical interest, as being effected *directly* from the Taylor series, whereas in dealing with the second class a preliminary transformation of the series into the more easily manipulated form of a definite integral seems to be essential.

A. *Functions formed by selecting terms from the exponential series.*—The general form of such functions is

$$f(\lambda)=\sum_{n=0}^{\infty}\frac{\lambda^{\phi(n)}}{\{\phi(n)\}\,!},$$

where $\phi(n)$ is a positive and continually increasing function which is integral for all integral values of n. It is easy to see that (in the ordinary notation) all such functions satisfy the inequalities

$$\mathrm{K}e^{r}/\sqrt{r}\leqq \mathrm{M}(r)\leqq e^{r}.$$

Moreover, if the increase of $\phi(n)$ is *regular and sufficiently rapid*, the nature of the zeroes associated with the essential singularity at infinity may be determined with much precision. The essence of the proof is to determine a series of circles on each of which the behaviour of $f(\lambda)$ is completely dominated by that of one term.

Suppose, *e.g.*,[3] $\phi(n)=n^3$. Then it can be proved that if

$$r=\mathrm{N}^3,\ \mathrm{N}\geqq \mathrm{N}_0 \qquad f(\lambda)=\frac{\lambda^{\mathrm{N}^3}}{(\mathrm{N}^3)!}(1+\epsilon_\lambda),$$

where $|\epsilon_\lambda|<\frac{\mathrm{K}}{r}$. Hence it follows that, round the circle $r=\mathrm{N}^3$,

$$f(\lambda)=\sqrt{\frac{2\pi}{r}}e^{r+ri\theta}(1+\epsilon_\lambda),$$

[1] *Acta Mathematica*, l.c., p. 367.

[2] Since the invariant factors of $|b-\lambda|$ and $|c-\lambda|$ are known to be linear, it seems quite hopeless to make any connection between these and $|a-\lambda|$.

[3] The increase of $\phi(n)=n^2$ is not quite rapid enough.

and from this it is an immediate consequence that the number of zeroes inside the circle is *exactly* N^3. Again, between the circles $r = N^3$ and $r = (N+1)^3$

$$f(\lambda) = \frac{\lambda^{N^3}}{(N^3)!}(1+\epsilon_\lambda) + \frac{\lambda^{(N+1)^3}}{\{(N+1)^3\}}(1+\epsilon_\lambda).$$

The $3N^2+3N+1$ zeroes which lie between the circles are given by the formula

$$r = N^3 + \frac{3}{2}N^2 + \ldots .$$

$$\theta = \frac{(2k+1)\pi}{3N^2+3N+1} + \rho$$

($k = 0, 1, \ldots 3N^2+3N$), ρ being very small. A more precise approximation to r would not be difficult, but seems superfluous.

The analysis is practically the same for more general forms of $\phi(n)$, and may be applied to other functions of the forms

$$\sum \frac{\psi(n)e^{\phi(n)}}{\{\phi(n)\}!}, \qquad \sum \frac{\psi(n)e^{\phi(n)}}{\{\phi(n)\}^{\phi(n)}},$$

&c.

B. *The function*

$$f(a, p, \lambda) = \sum_{n=0}^{\infty} \frac{\lambda^n}{(np+1)^a n!}$$

Concerning this function I have arrived at the following results :—

i. If p and a are positive, and a region, D, of the plane be defined by the inequalities $-\frac{1}{2}\pi < -\theta_0 \leqq \theta \leqq \theta_0 < \frac{1}{2}\pi$, then

$$f(a, p, \lambda) = \frac{e^\lambda}{(p\lambda)^a}(1+\epsilon_\lambda),$$

where ϵ_λ is a function of λ, which tends uniformly to zero when λ tends to ∞ along any path inside D, and λ^{-a} is real on the real axis.

ii. If D′ is the image of D in the imaginary axis

$$f(a, p, \lambda) = \frac{\Gamma\left(\frac{1}{p}\right)}{p^a\Gamma_{(a)}}(-\lambda)^{\frac{1}{p}}\{\log(-\lambda)\}^{a-1}(1+\epsilon_\lambda)$$

in D′, $(-\lambda)^{\frac{1}{p}}$ and $\{\log(-\lambda)\}^{a-1}$ being real on the (negative) real axis.

iii. If p and a are positive *and a integral* the zeroes of $f(a, p, \lambda)$ which lie above the real axis tend to the points

$$\left(a - \frac{1}{p}\right)\log(2k\pi) + (a-1)\log\log k$$
$$+ \log\frac{\Gamma\left(\frac{1}{p}\right)}{\Gamma(a)} + i\left[(2k+1)\pi + \frac{1}{2}\pi\left(a + \frac{1}{p}\right)\right],$$

where k is a large positive integer.

iv. If, on the other hand, a is zero or a negative integer $f(a, p, \lambda)$ has but a finite number of zeroes, which are all real and negative, reducing in fact to the product of e^λ by a polynomial. I have no doubt that the restriction introduced in iii. that a is integral is quite unnecessary, and that the formula holds for *all* real values of a save negative integral values, with a slight modification when a is negative. But I have not been able to prove this rigorously.

The function

$$\sum_{1}^{\infty} \frac{\lambda^n}{n^a . n!}$$

may be treated similarly, and so may other functions formed from the sine-function as $f(a, p, \lambda)$ is from the exponential function. Among various generalisations which may be made I may mention the following:—

If $\Theta(u)$ is real and continuous throughout (0, 1), the zeroes of the integral function

$$\frac{1}{p}\int_0^1 e^{\lambda u} u^{\frac{1}{p}-1}\,\Theta(u)du\ (p>0),$$

which lie above the real axis, tend to the points

$$\left(1-\frac{1}{p}\right)\log(2k\pi)+\log\Gamma\left(\frac{1}{p}\right)+\log\frac{\Theta(0)}{\Theta(1)}$$
$$+i\left[(2k+1)\pi+\frac{1}{2}\pi\left(1+\frac{1}{p}\right)\right].$$

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6. *Binary Canon Extension.* *By* Lieut.-Col. ALLAN CUNNINGHAM, *R.E.*

The author has prepared a table showing the least Residues (R), both + and − of the powers of 2 (say of 2^x), for all prime moduli (p), and also for all power of prime moduli (p^κ), up to p or $p^\kappa \not> 10{,}000$; the range of x is from $x \not< $ the modulus up to $x = 70$.

Thus it gives *at sight* the factors $\not> 10{,}000$ of $(2^x \mp R)$, and of $(2^x \mp 2^{x-a} \pm 1)$ up to $x = 70$ (when R is small). With some subsidiary work many other forms may be factorised, various congruences may be solved, and the Haupt-exponents (ξ) of small bases (a) may be found, *i.e.* the least values (ξ) giving $a^\xi = +1$ (mod p or p^κ).

This table is an extension of the author's Binary Canon (published in 1900) which extended only to moduli $\not> 1000$.

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7. *On the Theory of Transfinite Numbers.* *By* Dr. E. W. HOBSON, *F.R.S.*

FRIDAY, AUGUST 19.

SUB-SECTION OF ASTRONOMY AND COSMICAL PHYSICS.

CHAIRMAN—SIR JOHN ELIOT, K.C.I.E., M.A., F.R.S.

The Chairman delivered the following Address:—

When the suggestion was made to me that I should preside over this important sub-Section my first thoughts prompted me to decline the honour. The position had been filled during the past two years by two distinguished physicists, both of whom had dealt chiefly with the problems and the position of meteorological science, and hence I thought that it should be offered to some representative of cosmical physics. I also doubted whether an official meteorologist whose time has been chiefly given up to duties of administration could have anything of interest to communicate to you. However, on fuller consideration it occurred to me that I might be able to place before you some features of Indian meteorology leading up to and assigning, as I hope, adequate reasons for the study of a portion of the field of tropical meteorology as a whole.

My Address consists of three parts, viz.:—

1. A brief sketch of the broad features of the meteorology of India in their relations to the general meteorology of the Indo-oceanic region.

2. Statement of abnormal features of the meteorology of that area for the unique period 1892–1902 illustrating the remarks in the preceding sketch.

3. Suggestion of the co-ordination of the meteorological observations of the British Empire and the creation of a central office for the investigation of problems of general meteorology.

India is the most typical example of monsoon conditions, that is, of opposite air movements of six-monthly period which, in its case, depend on the annual temperature changes in the sea and land areas of the Indian Ocean and continent of Asia. The monsoon conditions in India are intensified by its unique position and topography. It projects southwards into the Indian seas over 15° of latitude, and is protected northwards by the vast barrier of the Himalaya Mountain range and Thibetan plateau. The axis of the Himalayan range is at least 2,000 miles in length and has an average elevation of over 20,000 feet. The extent of country over 10,000 feet in elevation to the north of India is from 300 to 500 miles in width. These figures will give some idea of the magnitude of India's northern barrier.

During one period of the year there is an outflow in the lower atmosphere from land to sea. The direction of the lower air drift in India is determined in part by the lie of the mountains and river valleys, and is from north-east over the greater part of the Indian seas. January is the month most typical of this air movement and of the accompanying weather conditions.

During another portion of the year the lower horizontal air movement is from sea to land. This movement is much steadier and more powerful and influential in every respect than the former. July and August are the months most representative of the totality of the weather conditions of this period.

Conditions similar to those of January prevail in their entirety from about the middle of December to the end of February or middle of March—the period known in India as the cold weather or cool season. The lower horizontal air movement in India during the period has its origin in Upper India, where it is very feeble, and whence it increases seawards and is of moderate force in the Bay of Bengal (mean force 2 to 3, Beaufort scale) and the Arabian Sea (mean, 2 to 4). It is fed to a certain extent by drift down the river valleys, and passes in the North-west India frontier hill ranges. There is, on the other hand, no general drift down the Himalayan river valleys or across the main ranges from Central Asia. The normal air movement in the Western Himalayas (and perhaps the whole range) is an alternating up and down, or day-and-night movement, depending upon the diurnal heating and cooling of the plains of Northern India. Hence India (in its lower air movement) is at this time completely shut off from Central Asia.

The lower air movement is continued over the Indian seas southwards to a region of vertical movement over a narrow belt a little to the south of the equator. This belt is also the goal of the lower air movement of the south-east trades circulation at this time. The equatorial belt of calms is hence the termination of the lower air movement of the south-east trades and north-east monsoon. It is chiefly an area of uptake, and of outflow northwards and southwards, to replace the lower air in flow from the distant south and north. The influx to the Indian land area occurs chiefly or entirely in the upper and (perhaps) middle atmosphere. There is also, as indicated by the wind directions in the lower Assam and Burma hills, an influx from the adjacent seas in the upper portion of the lower atmosphere.[1] The diurnal land and sea breezes alternate with great regularity on the west coast south of Gujarat during this period, but probably do not contribute to the general upper influx compensating in part or whole the lower outflow.

The circulation over the Indo-oceanic region hence consists at this time of two semi-independent circulations, with a common sink or goal for the lower air movement, which shifts with the season and with the relative strengths of the two movements. It is hence probable that they react on each other to some extent, and possible that general abnormal actions may affect the two similarly.

[1] In India the lower atmosphere may be defined as from 0 to 5,000 feet, the middle atmosphere from 5,000 to 15,000 or 20,000 feet, and the upper atmosphere above 20,000 feet.

The normal weather during the period is similar to that which obtains in anti-cyclonic periods during the summer in Central Europe—viz., the prevalence of light winds, with clear or lightly clouded skies, low humidity, moderate temperature, and large diurnal range of temperature, with a bracing, exhilarating atmosphere.

It is interesting to note that the air movement in India itself is from opposite directions in Northern India and the peninsula, with a belt of unsteady movement over the area of the Vindhya and Satpura hill ranges. The variations of weather conditions from the normal are as a rule inverse in these two regions—viz., Extra-tropical and Tropical India.

The season of the opposite air movement is present in its most complete form in July and August, and lasts from the beginning or middle of June to the middle or end of September. It commences as a lower air movement in an anticyclonic region over the South Indian Ocean, and is thence continued northwards to Abyssinia, South Arabia, India, and Burma. Persia, Afghanistan, and Baluchistan (where dry hot north-west winds chiefly prevail) are outside the field of this movement. The direction of the movement is from south, with more or less easting to the south of the equator, and with more or less westing to the north of the equator, dependent in part upon the earth's rotation and in part upon local conditions and the influence of neighbouring land areas, and hence more effective in the Bay of Bengal than in the Arabian Sea. This lower air current advances over an extensive tropical oceanic region before it reaches Southern Asia, and hence arrives charged with vast stores of aqueous vapour, which it discharges chiefly over the peninsulas of Southern Asia and the mountain region of Abyssinia.

The regions of rainfall indicate the areas of upward movement terminating the lower advance of the current. The circulation is undoubtedly maintained in large part by the release or addition of energy due to the condensation of its enormous stores of aqueous vapour. The lower air movement is of very considerable elevation, estimated at 15,000 to 20,000 feet in India. Above it is the outward upper return movement, in part only compensatory, and in part probably slowly filling up the Central and Southern Asian low-pressure region. The movement exhibits some interesting features in India, due to the fact that of the three areas to which it is mainly determined India alone is subject to a double influx from two sea areas in opposite directions. The current from the Arabian Sea passes eastwards across the Malabar, Konkan, and North Bombay coasts, the peninsula and Central India. The Bengal current is deflected in the north of the Bay of Bengal, and advances in a westerly direction up the Gangetic plain. Between the areas or fields of the two currents (roughly proportional to their relative strength and importance—viz., about 2 to 1) is a debatable area of variable winds and low pressure. This trough of low pressure varies in position with the relative strengths of the two currents. The cyclonic storms of the period, which are of comparatively frequent occurrence, advance along the trough. It is hence a factor of considerable importance in determining the distribution of the rainfall of the period. The trough is purely a resultant of the peculiar conditions of the air movement, and is not in cause of that movement; in other words, it is determined by it, and does not determine it.

The transformation of the double circulation of the north-east monsoon period into the single circulation of the south-west monsoon over the Indo-oceanic region next requires consideration. It is evident that the chief stages in this change are (1) the discontinuance of the vertical movement over the equatorial belt; (2) the extension of the trade winds of the south-east trades across the equatorial belt, with an accompanying increase of pressure and of horizontal air movement; (3) the continuance of that northerly movement over the Indian seas into the peninsulas of Southern Asia.

The marine data of the Indian seas collected during the past fifteen years establish fully that this transformation is primarily due to actions in the Indian Ocean, producing a movement resembling in many respects that of a bore or storm wave. The actual transition may hence be described as catastrophic, due to impulsive action.

It is preceded in India by a period of preparation (as it may be termed), when

pressure and other conditions are slowly established in Southern Asia, which directly contribute to the advance of the monsoon winds over the Indian seas, but which in no way assist the preliminary burst across the equator, the first stage towards the establishment of the south-west monsoon circulation.

This preliminary period is the hot-weather season, lasting from about the middle of March to the middle of June (on the average in Northern India). During this period temperature increases rapidly until the last week in May or first week of June, when maximum day temperatures ranging between 120° and 125° are usually recorded in the driest and hottest interior districts of Northern and Central India. Pressure decreases *pari passu* in the heated land areas of Southern Asia, which become areas of low pressure and indraught relative to the neighbouring seas. The indraught only extends to a comparatively short distance landwards and seawards from the coasts, more especially in the larger sea area, the Arabian Sea, over the centre of which light variable or northerly winds obtain even immediately before the advance of the monsoon currents. In the interior of Northern and in Central India exceedingly dry and hot westerly winds prevail with great steadiness.

The weather in India during this period depends almost entirely upon local thermal actions and contrasts of temperature and humidity conditions. Skies are generally free from cloud, but the air is more or less charged with dust and is excessively dry (humidities of 1 to 5 being of occasional occurrence in North-western India).

The characteristic features of the dry season are hence most strikingly exhibited immediately before the advent of the wet monsoon. There is no gradual change over the greater part of India from one to the other such as would occur if the furnace, or Central Asia hot area, theory were correct. Over small isolated portions of India, including Tenasserim, Arakan, Lower Burma, Assam, Bengal, and Malabar, thunderstorms giving more or less heavy downpours occur in increasing frequency during the period. The rainfall is considerable to large in amount in these areas, and is of much agricultural value in some districts—*e.g.*, in Assam for the tea crop. In those areas the transition to the rainy season is much less abrupt and spasmodic, the chief differences being that the rainfall in the wet season is more general and frequent, larger in amount, *and rarely accompanies thunderstorms.*

The transformation from the hot weather to the rains is usually effected between the 1st and 15th of June. It commences in the equatorial belt with a considerable increase of pressure and air movement accompanying a strong rush of southerly winds, the continuation of south-east trade winds, across the equator. If the burst be sufficiently strong the rush is continued northwards over the Indian seas as a wave of disturbance, squally weather, heavy rain, and much violent electric discharge or action, invading areas characterised previously by light and variable winds and fine weather. The disturbance usually increases with its northward advance, and frequently, when it reaches lat. 12° to 16° N., it concentrates into a cyclonic storm. Such a storm almost invariably marks the commencement of the monsoon in the Bay of Bengal, and in about two out of five years in the Arabian Sea. The advancing humid currents in the rear of these initial cyclonic storms or waves of disturbance march over the sea areas in a few days, and thence cross the coasts towards which they are determined by the low-pressure regions in the land areas of Southern Asia, where they produce an almost complete reversal or transformation of the weather conditions, the result of which is that moderately high temperature and small diurnal range of temperature, great humidity frequently approaching saturation, much cloud, and frequent rain obtain for the next three months over the greater part of India, until, in fact, the middle or end of September.

The reverse change—viz., the withdrawal of the humid south-west currents—then commences, and is a slow process, requiring usually from two to three months for its completion.

This is due to a gradual decrease of strength, and hence to a fairly continuous contraction of the field of the current, and also of its elevation or thickness. The

current first withdraws from North-Western India, being replaced by light, variable, or north-westerly land winds. These land winds increase in extension and volume with the continued contraction of the south-west monsoon current. The more important phases of the contraction and withdrawal of that circulation from India are of especial interest. The first phase, the retreat of the current from North-Western India, accompanies a rise of pressure over the Persian area and North-Western India, with a shift of the trough of low pressure from W.N.W. to N. or N.E. and corresponding change of direction of the average tracks of the storms of the period. This is followed after a short period of rain in North-Eastern India and Burma by a rise of pressure in Assam, Upper Burma, and Bengal, and the withdrawal of the monsoon current from those areas. The current then recurves over the centre of the Bay, in the same manner as during the monsoon proper over the north of the Bay and Bengal, and is directed or determined to the west or Madras coast of the Bay, which hence receives frequent rain during a short period of about two months—the rainy season of the eastern and southern parts of the peninsula south of Orissa and Ganjam.

These rains were formerly described as accompanying the setting in of the north-east monsoon on the Madras coast. That, however, is a misnomer, as the true north-east monsoon winds are dry land winds, and the rain-giving winds of this period in Madras are those of the south-west monsoon in its retreat or contraction down the Bay. The period during which this rainfall occurs is hence now usually termed the retreating south-west monsoon.

The year in India may hence be divided into two monsoons of nearly equal length, viz.:—

(*a*) The north-east or dry monsoon.
(*b*) The south-west or wet monsoon.

The first terms are based on the general direction of the air movement in the Indian seas during the periods, and the second on the most prominent feature of the weather in India itself. Of an average annual total rainfall of 41 inches (according to the most trustworthy calculation), at least 85 per cent. falls during the wet season, and only 15 per cent. during the dry season.

The dry monsoon in India is subdivided into—

1. The cold-weather period.
2. The hot-weather period or transitional period of preparation for the south-west monsoon.

The wet monsoon is subdivided into—

1. The south-west monsoon proper, or period of general rains.
2. The period of the retreating south-west monsoon and gradual slow establishment of the dry monsoon.

Each of these periods practically covers three months.

One of the most noteworthy features of the meteorology of India not referred to in the previous statement is that the storms of each period—viz., the cold-weather period, the hot-weather period, and the wet monsoon—are characteristic and special to the period. They are all in the broadest sense of the word cyclonic in character; but they originate under different conditions and exhibit very different features in each of those periods.

The disturbances of the cold weather are large shallow depressions which originate in the upper humid return current of the north-east monsoon circulation, chiefly in the Persian plateau region, and which drift eastward with a slight southing across Extra-tropical India. Storms do not occur south of the Deccan or peninsula-dividing ranges during this period. These storms are chiefly remarkable for the frequent development of stationary secondary depressions in the Punjab, usually of much greater intensity than the primaries; a feature of which, I believe, there is no parallel elsewhere. They are of great importance, as they give the main snow supply to the Western Himalayas and the light but

general occasional rain required for the wheat and other cold-weather crops of Northern India.

The storms of the hot weather are local disturbances of very limited extent, usually in large areas of slight depression, and are occasionally of remarkable intensity and great violence. In the areas to which the local sea winds of the period extend (more especially Bengal and Assam) they occur chiefly as local thunderstorms with violent winds and brief heavy downpours of rain, but sometimes as tornadoes rivalling those of certain districts of the United States in intensity and destructiveness. In the dry interior they occur as dust-storms, usually without rain, and are most violent in the driest districts, including Sind, the Punjab, and Rajputana. Occasionally, when the convective movement is especially vigorous, they develop into hailstorms of great intensity. The rainfall accompanying these hot-weather storms is of little general agricultural value except in the tea districts of Assam and Bengal.

Finally, the wet monsoon is characterised by the frequent occurrence of cyclonic storms of every degree of intensity and of very varying extent. The great majority of them originate in sea areas of nearly uniform temperature as disturbances in a massive current highly charged with aqueous vapour and subject to large variations of intensity and extension. The more prominent features of these storms, more especially of the most violent, including the hurricane winds, excessive rainfall, and the phenomena of the central calm and the accompanying storm wave, are too well known to require description. The chief importance of these storms, of which an average of about ten (of different degrees of intensity) occur every year during this period, arises from the manner in which they modify the distribution of the rainfall, discharging it abundantly over the districts traversed by the storms at the expense of the districts outside of their field.

The most important and variable feature of the weather in India from the practical standpoint is rainfall. Its value depends upon its amount and occurrence in relation to the needs of the staple crops. The measurement of rainfall is carried out, on a uniform system, at upwards of 2,500 rain-gauge stations. The average distribution of rainfall, month by month and for each season, has been determined from the data of about 2,000 stations. It should, however, be recognised that the probability that the rainfall will conform exactly to this distribution in any year is nil. Average rainfall charts represent a distribution about which the actual varies from district to district more or less considerably, the local variation for prolonged periods being practically compensatory. Such mean or normal data and charts are undoubtedly of value, more especially for the determination of rainfall anomalies and their relations to pressure, temperature, and other anomalies. There is apparently a tendency to assign a greater value to these charts of mean rainfall distribution than they deserve. Charts showing the amount and time distribution of the rainfall best suited for the requirements of the staple crops would—for India at least—be more interesting and valuable. This is a work that I regret has, for various reasons, not yet been carried out by the Indian Meteorological Department.

In most regions in India a moderate variation (positive or negative) in the amount of the rainfall is of comparatively small importance, more especially if the precipitation occurs in amount and at intervals suited to the requirements of the crops. During the thirty-year period 1874–1903 there were six years in which the distribution of rainfall affected to a serious extent the crop returns over large areas, and the rainfall was not compensatory. In four of these years the drought was so severe and widely spread as to occasion famine, with its attendant calamities, over large areas. Severe droughts and famines occur at very irregular intervals. A noteworthy feature is that they frequently follow in pairs separated by intervals of two to four years.

The previous statement of the meteorology of India has indicated the chief conditions which affect the crop returns seriously or disastrously over large areas in India. They may be summed up briefly as follows:—

(*a*) The dry monsoon. Absence or unusual feebleness of cold-weather storms.
(*b*) The wet monsoon. General feebleness of the monsoon current, due either

to corresponding feebleness of the south-east trades, or to unusual diversion to East Africa, or local feebleness in a part of India due to local conditions, or to abnormal diversion to other rainfall areas in South Asia. These conditions give rise in the areas affected to one or more of the following features:—

(1) Prolonged delay in the commencement of the rains.
(2) Scanty rainfall during the season, with prolonged periods of fine, clear, hot weather.
(3) Early termination of the rains.

These features are as a rule more marked in the drier districts of the interior than in the coast districts. The effect on crop production is greatest and most disastrous in the following areas:—

(1) Central Burma.
(2) The Deccan, including the Bombay and Madras Deccan districts, and Hyderabad.
(3) North-Western and Central India, more especially the South Punjab, East Rajputana, and the United Provinces.

The following important inferences are based upon the preceding presentation of facts and the experience of the past thirty years:—

(1) The lower air movement of the south-west monsoon is the northward extension of the lower movement of the south-east trades. The latter is a permanent feature of the Indo-oceanic region, and the former a periodic invasion of the Southern Asian seas and peninsulas initiated over equatorial regions and propagated northwards to the southern mountain barrier of the Central Asian plateau.

(2) The primary factors determining this impulse across the equator (the first stage of the establishment of the south-west monsoon) are to be sought in the permanent field of the south-east trades, and are not due to actions in the heated areas of Southern or Central Asia.

(3) The pressure conditions in the heated areas of Southern Asia and North-East Africa determine the direction, volume, and intensity of the advance over the Indian seas to what may be termed three competing areas for rainfall (viz., Abyssinia, India, and Burma). These conditions are hence important factors in the third stage of the advance of the south-west monsoon current.

(4) The movement when fully established by these actions over the Southern Asian seas and peninsulas is continued—1st, by the momentum of the lower circulation; 2ndly, by the release of energy accompanying aqueous vapour condensation; and 3rdly, by thermal actions in Southern Asia, due to direct solar activity. The termination of the lower horizontal current by vertical movement occurs irregularly over the areas of frequent heavy rain in Southern Asia and Abyssinia, and not over a heated area in Central Asia.

(5) The total volume of aqueous vapour brought up by this circulation not only varies in amount from month to month during the season, but also from year to year. The largest variations (seasonal and annual) depend chiefly, if not entirely, upon actions in the source of supply—viz., the Indian Ocean. If those actions determine an increased or diminished supply across the equator into the Indian seas, there is a corresponding variation in the total precipitation of the three competing areas. Amongst such causes and actions may be prolonged and untimely diversion of the south-east trades into East Africa, as in 1896, or general weakness of the air movement over the Indian Ocean, probably accompanying a displacement and decreased intensity of the southern anticyclone, as in 1899.

(6) The relative distribution of the total rainfall in the three areas of discharge of the aqueous vapour of the monsoon currents probably depends upon the relative intensities of the pressure conditions established during the hot weather, which are continued for a part or the whole of the monsoon by actions depending

on the rainfall resulting from the initial pressure conditions—an example of the persistence of meteorological conditions and actions which is a prominent feature of Indian meteorology. The total rainfall of each of the three areas may differ considerably from the normal, but there may be partial or complete compensation on the whole. Thus it is the general (but not the invariable) rule that the rainfall variations in Burma and Assam are usually inverse to those of North-Western India and also of India as a whole.

(7) The distribution of the rainfall in any one of the three competing areas (but more especially in India as the largest) may vary widely from the normal—considerable deficiency in some areas accompanying considerable excess in others. This in India is undoubtedly due to local conditions—*e.g.*, local excess or deficiency of pressure at the commencement of the period and established during the previous hot weather. These pressure variations usually accompany abnormally prolonged and heavy snowfall or very scanty snowfall in the Western Himalayas.

(8) Local or general drought in India during the south-west monsoon may hence be due to—

(*a*) General weakness of the south-east trades circulation.

(*b*) Diversion of an unusually large proportion of the south-east trades to South-East or East Africa during the monsoon period.

(*c*) Larger diversion than usual of the monsoon currents to Burma or Abyssinia.

(*d*) Very unequal distribution in India itself, due to local conditions established during the antecedent hot weather.

These factors are given in the probable order of their importance.

(9) Scanty rainfall or drought during the dry season or north-east monsoon in Northern India results from absence or unusual feebleness of the cold weather storms which are the sources of rainfall at that time.

(10) The most prolonged and severe droughts in North-Western and Central India are due to the partial or complete failure of the rainfall of at least two seasons in succession.

(11) As the two circulations in the Indian oceanic region have a common goal in the dry season (more especially from December to March), it is probable that variations in the strength of one circulation (more especially the larger) will modify the field and strength of the other circulation. It appears that this relation would be shown most strongly between the southern circulation and the upper movement of the northern circulation. And, as cold weather storms are disturbances in that upper movement, it is possible—if not probable—that the larger variations in the number and intensity of the cold-weather storms and the amount of the cold weather precipitation may be related to conditions in the south-east trades regions.

(12) There appears to be little or no relation between the position and intensity of the Central Asian anticyclone and the number of the cold-weather storms and rainfall of Northern India in any season.

The meteorology of the period 1892–1902 is of especial interest for its confirmation of the above inferences, more especially the phenomena of the variations of rainfall in India and the causes or actions to which they are due. The year 1891 was noteworthy for a severe local famine in Rajputana and the adjacent districts to the north and east consequent on prolonged and excessive snowfall in the Western Himalayas during the winter of 1890–91. The following gives a brief summary of the more prominent feature of the meteorology of this unique period:—

1. The eleven-year period 1892–1902 corresponds in length to the sun-spot period, and it may be divided into two periods of unequal length—a short period of excessive rain and a long period of deficient precipitation. The maximum of the first period was in 1893. The second period had three strongly marked minima in 1896, 1899, and 1901, that of 1899 being the absolute minimum. The following table gives, for convenience of reference, data of the mean annual and

seasonal variations of rainfall of the Indian land area for each year of the period:—

Variation of Mean Actual Rainfall of Period from Normal.

—	Cold Weather: January and February	Hot Weather: March to May	South-west Monsoon. Complete Period: June to December	Whole Year
1891 . . .	+0·34	+0·37	− 4·25	− 3·54
1892 . . .	−0·39	−0·21	+ 5·69	+ 5·09
1893 . . .	+1·63	+2·72	+ 4·72	+ 9·07
1894 . . .	+0·48	−0·76	+ 6·75	+ 6·47
1895 . . .	−0·01	−0·23	− 1·95	− 2·19
1896 . . .	−0·42	−0·82	− 3·59	− 4·83
1897 . . .	−0·01	−0·12	− 0·02	− 0·15
1898 . . .	+0·50	−1·00	+ 0·93	+ 0·43
1899 . . .	−0·38	+0·58	−11·34	−11·14
1900 . . .	−0·02	−0·25	− 0·26	− 0·57
1901 . . .	+1·47	−0·48	− 5·12	− 4·13
1902 . . .	−0·57	+0·16	− 1·64	− 2·05
Normal roughly.	1 inch	5 inches	35 inches	41 inches

2. The following gives the chief features of the rainfall of the first period, 1892–4:—

(*a*) The excess was almost as marked in the dry as in the wet season. This is strongly shown in the year 1893 of maximum excess.

(*b*) The excess was on the whole more strongly exhibited in the field of the Bombay than of the Bengal current.

(*c*) The rainfall of the dry season was as markedly in excess in Persia, Baluchistan, Afghanistan, and the Himalayan area as in Northern India.

(*d*) The maximum height of the Nile floods (in September) was above the average. They were abnormally high in 1892 and 1894.

(*e*) The rains were favourable over Australia and South Africa during this period, according to the reports received in India.

(*f*) Hence, as a general inference, the rainfall was in general excess in each year of the period over the Indo-oceanic region, and not only in the south-west but also in the north-east monsoon in Southern Asia.

3. The chief features of the rainfall of the second period, 1895–1902, in the Indo-oceanic region were as follows:—

(*a*) The rainfall was as deficient relatively to the normal in the cold weather as in the rains or wet season.

(*b*) The cold-weather or winter precipitation was almost continuously in marked defect in Asiatic Turkey, Persia, Afghanistan, Baluchistan, the Himalayan area, and South Thibet. The opposite variation obtained in Central Asia, as is shown by available data for Tashkend, Samarcand, Irkutsk, and other stations.

(*c*) The storms of the cold weather were fewer in number and feebler in character in each year of the period than on the average of the preceding sixteen years 1876–91.

(*d*) The south-west monsoon rainfall was most largely in defect in the interior districts served by the Bombay current.

(*e*) There was a marked tendency in each year for late commencement and early withdrawal of the monsoon currents, and for deficient rainfall throughout the whole season over the greater part of India. These features were very pronounced in the years 1896, 1899, and 1901.

(*f*) The most remarkable feature of the period was that the region to the south of the equator, including South and East Africa, Mauritius, and Australia, was similarly affected.

In India the years 1896 and 1899 were years of severe drought, followed by famine over very large areas. The area in which the crops failed more or less completely was about 250,000 square miles in extent in 1896 and 500,000 square miles in 1899. In the 1899–1900 famine upwards of 6,500,000 people were on famine relief for several months. The loss of cattle due to failure of water and fodder was very great, numbering many millions. In some districts from 90 to 95 per cent. of the cattle died off from slow starvation and want of water. In New South Wales and Queensland almost continuous drought prevailed from 1896 to 1902. It is estimated that over fifty millions of sheep, value 12,500,000*l.*, were lost in New South Wales during these seven years of drought.

Mr. Hutchins, Conservator of Forests, Cape Town, states that drought prevailed more or less persistently over the Karoo region in South Africa from 1896 to 1903, and that cattle and sheep perished by millions. He also states that the drought extended to British Central Africa from 1898 to 1903.

The previous statements evidence the continuity, extension, and intensity of the drought.

The Nile floods followed very closely the variations of the rainfall in Western India. The floods of the years 1899 and 1901 were both amongst the lowest on record. This shows that the rainfall in the Abyssinian region was more or less generally in defect during the period and most largely in the years 1899 and 1901, when the rainfall of the Bombay current was very deficient.

Hence, as a general inference, the period 1895–1902 was characterised by more or less persistent deficiency of rainfall over practically the whole Indo-oceanic area (including Abyssinia). The economic results in the dry interior districts of India, South Africa, and Australia were the same—large loss of cattle and great loss of capital. The drought in Southern Asia was as marked in the north-east as in the south-west monsoon, and hence the variation was not seasonal but general.

The variations of temperature, humidity, and cloud in India during the whole period were large and in direct accordance with the rainfall. In other words, during the period 1892–94 the air was damper, with lower temperature than usual and cloud above the normal. On the other hand, from 1895 to 1902 temperature was steadily in excess, cloud less than usual, and humidity below the normal.

The most remarkable variation was that of the solar radiation as indicated by observations of the solar radiation thermometer (black bulb *in vacuo*).

The most interesting feature of the meteorology of the period 1892–1902 is that the variations of the solar insolation are the inverse of those which might have been expected from the cloud and humidity data. In other words, solar radiation was in excess in the period of increased humidity and cloud, and in defect during the greater part of the period of drought, decreased humidity, and cloud. The series of eight curves exhibited, out of a larger number prepared from the data of a number of stations in India at which these observations are carefully recorded, show the most important facts, and indicate that there was a continuous decrease of insolation on the average of all stations from 1891 to 1902. The curves for Aden, Calcutta, and Leh, it will be seen, agree in their most important features. The observations are quite concordant and probably represent a most important feature of the period. They indicate either a continuous and considerable decrease of emission of solar energy during the period, or unusually large absorption in the upper atmosphere. In order to decide this question comparison is necessary with similar data for other large areas, as, for example, Europe and North America. It is, however, clear that in India the insolation data of this unique period are of exceptional interest and value.

The preceding statements have shown that variations of rainfall for prolonged periods similar in character have occurred, and may hence occur again, over the very large area including the Southern Asian peninsulas, East and South Africa,

Australia, and, perhaps, the Indian Ocean. The abnormal actions or conditions giving rise to these large and prolonged variations must hence be persistent for long periods, and be effective over the whole of that extensive area, and hence cannot be inferred with certainty from the examination of the data of one small portion of the area affected—*e.g.*, India. The variations undoubtedly accompany variations in the complete atmospheric circulation over the Indo-oceanic area, and the effective forces or actions must be such as to influence the whole movement in a similar manner in the two monsoons or seasons of inverse conditions in Southern Asia. This inference furnishes a very strong reason for the conclusion that the meteorology of the whole area similarly affected from 1892 to 1902 should be studied as a whole, and not in fragmentary detail by various weather bureaus, and, as at present, without any co-ordination of the results of these bureaus.

The discussion has also indicated that the south-west monsoon current is a periodic or intermittent extension of the permanent circulation of the south-east trades to the peninsulas of Southern Asia, and also that variations in the strength, volume, and direction of movement of the latter affect the extension, volume, aqueous vapour contents, and precipitation of the south-west monsoon currents in Burma, India, and Abyssinia. This fact further emphasises the necessity for the co-ordination and systematisation of the work of observation in the Indo-oceanic meteorological province and the continuous and systematic examination and discussion of observations for the whole of that area.

It is, of course, possible that it may be necessary to extend this work to a larger area than the Indo-oceanic region. For Sir Norman Lockyer and Dr. Lockyer have shown that similar pressure variations to those of Bombay occur over a large portion of the Eastern Hemisphere, and variations of opposite sign (similar to those of Cordova) over a considerable part of the Western Hemisphere.

The Indian Meteorological Department, with the sanction of the Government of India, is now arranging to collect and tabulate data for the whole area between the Central Asian winter anticyclone and the permanent South Indian Ocean anticyclone, and to utilise the information for the investigation of the causes of the large and general variations of rainfall in Burma and India from year to year. This extension of its labour is recognised as necessary for the improvement of the seasonal forecasts, an important feature of the work of the Department the value and importance of which are fully recognised by the Government of India.

Possibly the practice of the Indian Meteorological Department in the preparation and issue of long-period or seasonal forecasts is considered to be not only unscientific, but not justified by comparison with facts. Professor Cleveland Abbé, in his paper on 'The Physical Basis of Long-range Weather Forecasts,' expresses his opinion that 'we are warranted in saying that during the thirteen years (1888–1900) the only real failure has been that of the prediction of the monsoon season of 1899, the year of phenomenally great drought in that country.' This opinion is probably more favourable than I should myself give, but it is the opinion of an independent meteorologist eminently qualified to give a judgment in the matter.

My own opinion with respect to weather forecasts is that there appears to be too strong a desire for absolute accuracy, possibly due to public and newspaper criticism. Certainty is not possible in weather forecasts based on imperfect information, and in which the introduction of a single unknown factor in regions beyond observation—*e.g.*, the upper or middle atmosphere—may completely alter the course of events. Percentages of success are an inadequate measure of the utility of forecasts. To be of real value as estimates of utility they should be calculated rather on the information required, and which might be reasonably expected, than on that actually given.

It appears to me that the striving after perfection in short-period forecasts to the exclusion of other claims is impeding the extension and progress of meteorology in other useful directions. It is absolutely essential that officials preparing or utilising forecasts should recognise that every forecast is based on imperfect information and experience, and hence that all important forecasts should be

expressed as probabilities, and, whenever desirable, an estimate of the value of each probability be given.

The Government of India desires to have these seasonal forecasts, and has ordered its Meteorological Department to furnish them. The Government encourages the work, provides the additional means required by the Department for its proper performance, and issues the forecasts only to those who will use them as probabilities for practical guidance.

The importance of the work of seasonal forecasting in India may be judged from the following remarks:—

India is almost exclusively an agricultural country, with a population of nearly 300 millions. The material prosperity of practically the whole people is determined by the amount and distribution of the periodic rains. The variations in the amount and period of the rains are occasionally so great as to produce the most disastrous results in the staple crops over large areas. In 1899, for example, the crops failed more or less completely over an area several times the extent of England.

There is probably no country where the meteorological problems, of which these rainfall variations form one feature, are of greater interest or more practical importance. The daily weather and rainfall reports are studied during the greater part of the year with the closest attention by the officials, from the Viceroy downwards.

The Government is hence keenly interested in meteorological observation and investigation, and is most anxious to improve its meteorological service and utilise it for practical purposes, of which seasonal forecasting is one of the most important. To give two examples. A reassuring forecast at a critical period, followed by its realisation, might be of the greatest value to the agricultural population of a large province, as well as to the local and Imperial Governments. Again, a statement or forecast the probability of which was, say, at least 10 to 1 that the rains would fail more or less completely during a season over a large area might enable the Government to carry out early prudential measures for relief in the most economical and effective manner with the means at its disposal. The preparation and issue of seasonal forecasts will hence, I am confident, be in the future, as in the past, one of the most important duties of the Indian Meteorological Department.

There are several points in connection with weather forecasting in India which it is desirable should be borne in mind. The first is that weather in India is distinguished rather by the massiveness, intensity, and persistence of abnormal features than by the frequency and rapid succession of important weather changes. It is chiefly on this account that daily weather forecasts, even if they could be communicated with the necessary rapidity, are of no value to the Indian agricultural population. Also, the empirical knowledge of the significance of the important variations as factors determining or indicating future weather accumulates much more slowly than in Europe, and it is hence doubly important that in India the empirical knowledge derived from very limited experience should be, so far as possible, regulated and controlled by theory and scientific knowledge. It should also be remembered that there are large differences between the meteorology of tropical and temperate regions, and also between the relation of crops to weather in India and England. The instincts, habits, beliefs, education of the body of the people in England and India also differ very widely. Hence the possibilities of the practical applications of meteorological science in India cannot be judged from the European standard, and may from that standpoint be unique.

The possibilities of usefulness of the work of seasonal or long-period forecasting in India are almost unlimited. To be acceptable and useful to the agricultural population of areas liable to drought they should be fairly accurate with respect to the dates of commencement and termination of the periodic rains, their general character, and the probable occurrence of prolonged breaks likely to be injurious to the chief food crops. If the forecasts were found to be fairly reliable in these respects, it is quite certain that the agricultural population would value them and

use them. Indications of a growing belief in the utility and value of this feature of the work of the Department by the people in different parts of India are not wanting.

The Government of India have sanctioned large changes in its Meteorological Department in order to enable it to carry out the extensions of work that recent experience has shown to be desirable. The Department is kept in touch with scientific opinion and judgment at home through the Observatories Committee of the Royal Society. The relations to other scientific departments in India are maintained by a special committee termed the Board of Scientific Advice. The scientific staff has been largely increased. The solar physics observatory at Kodaikanal and the magnetic observatory at Bombay have been placed under the Meteorological Department with a view to the complete co-ordination of the departments of scientific investigation for which they are maintained. Observational data for the whole Indo-oceanic area are now being collected and tabulated with a view to the early publication of daily and monthly weather reports and charts of that area.

The objects of this last extension have already been indicated. It will afford the Indian meteorologists the data necessary for the investigation of the extension and intensity of the more important variations in the meteorology of the whole region, to correlate the abnormal features in the atmospheric circulation over the area, and more especially to ascertain the causes of the occasional failure of the monsoon rains in India. Finally, it will, it is hoped, enable the Department to collect the information and acquire the additional experience necessary in order to render the seasonal forecasts more reliable and satisfactory than they have been during the past six or seven years.

The area to be dealt with (viz., the Indo-oceanic area) is partially covered by a number of independent meteorological systems, including those of Egypt, East, Central, and South Africa, Ceylon, Mauritius, the Straits Settlements, and Australia. Large areas, as, for example, Arabia, Persia, Afghanistan, Thibet, and the greater number of the islands of the Indian Ocean, are now almost completely unrepresented.

The departments controlling these systems work independently of each other, chiefly for local objects, and are in no way officially correlated or affiliated. Their methods of observation and of discussion and publication of meteorological data differ largely. It is hence difficult, if not almost impossible, to make satisfactory comparisons of the data, and trace out for the work of current meteorology the extension or field of similar variations, their relations to each other, and their probable influence on the future weather.

The work which should be carried out in order that the investigation of the meteorology of the Indo-oceanic area might be effective and as complete as possible includes the following:—

(1) The extension of the field of observation by the establishment of observatories in unrepresented areas, and the systematic collection of marine meteorological data for the oceanic area.

(2) The collection and tabulation of the data necessary to give an adequate view of the larger abnormal features of the meteorology of the whole area.

(3) The direction by some authoritative body of the registration, collection, and tabulation of observations by similar methods in order to furnish strictly comparable data for discussion.

(4) The preparation of summaries of data required as preliminary to the work of discussion, and for the information of the officers controlling the work of observation in the contributory areas. The earliest publication of the data should be regarded as essential for the use of officers issuing seasonal forecasts.

(5) The scientific discussion of all the larger abnormal features in any considerable part of the area and their correlation to corresponding or compensatory variations in the remainder of the area by a central office furnished with an adequate staff.

(6) Possibly, sufficient authority on the part of the central office to initiate special observations required for the elucidation of special features for which there are no arrangements in the general work of the various systems.

The Indian Meteorological Department is making preparations to carry out a portion of this work; and will undoubtedly do the best it can single-handed with its limited means. It cannot do the work fully and as it ought to be done. It can do nothing which requires authoritative control over the remaining meteorological systems in the Indo-oceanic field. It is collecting information from those who are willing to supply it, and will utilise it for its special purposes.

It is evident the work can only be carried out fully by the co-operation of the various systems subject to limited control by a central office with acknowledged imperial or general authority behind it. The most important part of the work from the standpoint of the science of meteorology is the comparison and discussion of the whole body of observations. The constitution, position, and authority of the central office is hence of the greatest importance. It is quite certain that none of the meteorological systems directly concerned can provide such a central office. If the work is to be carried out fully and systematically it can only be arranged for in England, and by the English Government assuming the general direction and control. At the present time a section of the English Meteorological Office is devoted to the study of oceanic meteorology for the information of mariners. Another section should be created for the study of imperial meteorology for the benefit of its dependencies and colonies. I have reason to believe that the Government of India would contribute its share towards the cost of this extension of work.

In the preceding remarks are given the chief reasons for an important extension of work now in progress in the Indian Meteorological Department, an extension which can only be carried out imperfectly by that Department, but which could be performed with most valuable scientific results by the co-ordination of the labours of the weather bureaus concerned, with a central institution or investigating office in England under Government control.

Perhaps I may be permitted, from my Indian experience, to add some general remarks bearing on the methods and progress of meteorological inquiry.

In India the collection and publication of accurate current data relating to rainfall and temperature is required for the information of Government in its various Departments. The collection and examination of pressure and wind data by a central office with a view to the issue of storm and flood warnings is equally necessary. This work may, perhaps, be described as pertaining to descriptive or economic meteorology.

Economic meteorology, so long as it deals only with actual facts of observation, is not a science. Forecasts belong to the same department or branch of meteorology. They may be based on scientific theory and be obtained by scientific methods or the utilisation of empirical knowledge. The latter method is probably sufficient for by far the greater part of short-period forecast work, but the final development of that work and the preparation of long-period forecasts require the application of exact scientific methods and knowledge. And it is, perhaps, not too much to say that the extension of the range or period of forecasts is a measure of the progress of meteorology as a science. India, by the simplicity and massiveness of its meteorological changes (and perhaps Australia and Africa), appears to be best suited for the earliest experiments in this work.

India is, however, poor, not only in material wealth and capital as compared with England, but also in the appliances and means of scientific investigation, and hence looks to England for assistance and guidance in scientific matters. Unfortunately, England lags behind, not only the United States and Germany, but even behind India, in the important field of scientific meteorological inquiry. It will suffice to give a single illustration of the anomalous and inferior position which England takes in such matters.

All meteorologists and scientific men generally are agreed that the exploration of the middle and upper atmosphere by any available means—*e.g.*, kites, balloons, &c.—is of the utmost importance at the present stage of meteorological inquiry. The United States, France, and Germany have taken up the work vigorously. The English Meteorological Office is unable, for want of funds, to share or take any part in the work. The force of scientific and public opinion is apparently

powerless to move the English Government to grant an extra five hundred pounds annually for this work. The English Government, on the other hand, some time ago suggested that the Indian Meteorological Department should assist. The Government of India, recognising the importance of the work, has provided the funds and sanctioned the arrangements necessary in order that its Meteorological Department may march with the most progressive nations in this investigation.

India has no body of voluntary observers or independent scientific workers and investigators. Whatever is required to be done to extend practical and theoretical meteorology can only be effected by the Government Department to which that work is assigned, with the sanction and at the cost of the Government—which naturally considers chiefly its practical wants in relation to its limited resources. It is, from one point of view, a painful if not quite an unexpected experience to me, on my retirement, to find that the Government of India is, in its attitude towards meteorological inquiry, more advanced, more liberal and far-sighted than the English Government, and that England has not yet taken up seriously the work of scientific meteorological investigation. There are undoubtedly too many observations and too little serious discussion of observations. The time has arrived when investigation should go hand in hand with accurate observation, and should direct and suggest the work of observation, and also that the sciences directly related to meteorology should be considered concurrently with it. There are undoubtedly definite relations between certain classes of solar phenomena and phenomena of terrestrial magnetism. The probability of definite relations between solar and terrestrial meteorological phenomena is also generally admitted.

Data for the determination of these relations are being rapidly accumulated, and numerous problems connected therewith are waiting and ripe for investigation. They are too large and complex to be undertaken by present English methods, and can only be attacked by a body of trained investigators under arrangements securing the continuity of method and thought requisite for the prolonged systematic inquiry gradually leading up to their complete solution.

It would hence be desirable to enlarge the scope of the central institution I have suggested, so as to include in its field of labour the investigation of the relation between solar and terrestrial meteorology and magnetism, so far as they can be solved by the comparison of the observations of the British Empire.

The central institution would thus have large and definite fields of work and most interesting problems for investigation. It would hence contribute towards the formation of a body of scientific meteorological investigators adequate to the importance and wants of the empire, and be of the highest educational as well as scientific value.

My predecessor in this position, Dr. Shaw, the head of the English Meteorological Office, made some remarks in his Address last year which deserve repetition in connection with this idea. He said: 'The British Empire stands to gain more by scientific knowledge, and to lose more by unscientific knowledge, of the matter than any other country. It should from its position be the most important agency for promoting the advance of meteorological science—in the first place because it possesses such admirable varying fields of observation, and in the second place because with due encouragement British intellect may achieve as fruitful results in this as in other fields of investigation.'

The establishment of the central institution as suggested above would provide a remedy for the defects pointed out by Dr. Shaw. The reorganisation of the English Meteorological Office is, I believe, under consideration. Is it too much to hope that a strong expression of opinion on the part of the British Association, and the influence of the learned University at which its present meeting is held, would induce the English Government to spend an additional 5,000*l.* or 10,000*l.* annually for the promotion of meteorological investigation and the establishment of a central Imperial institution in London in connection with its Meteorological Office?

The following Papers were read:—

1. *The Spectra of Sun-spots.* *By the* Rev. A. L. Cortie, *S.J., F.R.A.S.*

The paper contains a reduction of all the observations of sun-spot spectra taken at Stonyhurst during the years 1883–1901 with a 12-prism spectroscope attached to either the 8-inch or 15-inch equatorial. A discussion of the observations of the spectra of ninety sun-spots, observed during the period 1883–1889, appeared in the 'Memoirs R.A.S.' vol. l., and of twenty-four other spots observed in the period 1890–1901 in the 'Monthly Notices R.A.S.' vol. lxiii. No. 8. All the observations have been taken by the same observer, and are not restricted to a few lines, but on each occasion some particular region of the spectrum between B and D has been selected for detailed study, after a general view of this part of the spectrum had been secured for determining the most widened lines. The earlier observations of the widened lines were catalogued according to Angström's wave-length numbers, as corrected in the British Association 'Catalogue of the Oscillation-frequencies of the Solar Rays' (1878); the later observations according to Rowland's numbers. The present catalogue of 346 widened lines between wave-lengths 5884·03 and 6867·46, which combines all former lists, is based on Rowland's numbers, and contains 5486 individual observations.

The chief phenomena in the spectra of sun-spots are, as regards the general absorption, a want of uniformity of blackness in various regions of the spectrum sometimes observed, and, as regards the selective line absorption, the widening of lines, darkening of lines without widening, displacement of lines, obliteration of lines, extension of the widening through the penumbra, reversal of lines, hazy fringes to lines, and spot-bands. The following tables contain, the one, the mean relative widening of the lines of the chief elements identified, and the other, a list of the most widened lines. The numbers for relative widening are estimated in terms of the normal width of the line multiplied by the factor 10, and for intensities are taken from Rowland's Catalogue, where 1 is a line just clearly visible, and successive zeros indicate increasing degrees of faintness.

The tables show the importance of faint lines of vanadium and titanium in the sun-spot spectra ('Monthly Notices R.A.S.' vol. lviii. No. 7). These faint lines have been always, and at all times of the sun-spot period, among the most widened lines (*loc. cit.* vol. xlix. No. 8; vol. lxii. No. 7). The observations give no evidence of a crossing of the most widened lines at an epoch between sun-spot maximum and minimum. They show, however, that the iron lines are more affected in minimum than in maximum spots; no conclusion can be drawn as to a difference of character and temperature between maximum and minimum spots from the behaviour of such faint widened lines. The iron lines brightened in the chromosphere, which are mostly arc lines, are not differently affected in sun-spots from lines not brightened. The widening of some oxygen lines in sun-spots in the *a* band seems to be a real phenomenon, the single hydrogen line (C) is generally thinned, and almost reversed over spots, and frequently reversed and distorted in their immediate neighbourhood. If oxygen and hydrogen are present in sun-spots, water-vapour might be formed over them. Spot-bands sometimes seen (*loc. cit.* vol. xlvii. No. 1) are a probable witness to a reduction of temperature sufficient for the formation of compounds. But the widened lines accredited to water-vapour occur generally in crowded parts of the spectrum, so that the widening may be really due to faint solar lines in juxtaposition with them. The predominance of vanadium and titanium in sun-spots is important in view of Mr. Fowler's recent identification of the flutings in Secchi's third-type stars as due to titanium or a titanium compound, and Sir Norman Lockyer's matching of the lines intensified in the spectrum of Arcturus with lines of the same element. Professor Hale has also shown that many of the lines in the fourth-type stars are coincident with lines observed as widened in sun-spots by Mr. Maunder and myself.

TABLE I.—*Relative Widening of the Lines of each Element.*

Element	Total Number of		Mean Relative	
	Lines	Observations	Widening	Intensity
Vanadium	11	186	12·3	00·0
Titanium	13	207	7·7	1·5
Calcium	18	734	5·1	6·3
Sodium	4	255	5·1	13·6
Nickel	28	566	4·5	2·2
Manganese	4	123	3·8	4·8
Iron	123	2593	3·7	3·9
Iron (chromosphere lines)	35	863	3·6	4·6
Oxygen?	15	90	6·4	1·7
Water-vapour	47	364	4·3	0·8

TABLE II.—*Lines with the Greatest Mean Widening.*

Wave-length	Origin	Spots	Relative	
			Widening	Intensity
5978·77	Ti	33	11	1
99·92	Ti	23	10	0
6005·77	Fe	21	9	1
39·95	V	42	10	0
6126·44	Ti	15	10	1
54·44	Na	16	9	2
60·96	Ca	41	9	3
61·50	Na			4
99·40	V	26	14	0
6210·90	...	12	12	00
43·06	V	45	28	000
61·32	Ti	29	9	1
74·87	...	11	12	00
6306·02	O	18	16	2
6405·98	...	10	9	00

2. *The Temperature of the Stars. By* Sir NORMAN LOCKYER, *K.C.B., F.R.S.*

3. *Criteria of Stellar Temperatures. By* H. F. NEWALL, *F.R.S.*

4. *The Short-period Barometric See-saw and its Relation to Rainfall. By* WILLIAM J. S. LOCKYER, *M.A., Ph.D., F.R.A.S.*

The first portion of this paper dealt with the short-period barometric see-saw which has been found by the author and Sir Norman Lockyer to exist between two antipodal regions on the earth's surface. This investigation, which has been published by the Royal Society,[1] has already been referred to in detail.

The essence of the second portion may be briefly summarised in the following words:—

The variation of the barometric pressure over India from year to year is the *inverse* of that over Cordoba, in South America—that is, when the pressure over

[1] *Roy. Soc. Proc.*, vol. lxx. p. 501, vol. lxxi. p. 135, and vol. lxxiii. p. 457.

India is in excess of the normal for a year or so, that over South America is deficient or below normal.

A study of this pressure variation for places widely scattered over the earth's surface shows that the earth's surface may be divided into two parts: one part behaving more or less like India, and the other like Cordoba. A classification of pressures of these two regions shows that a dividing line may be drawn round the earth, on the opposite sides of which barometric see-saws take place.

As it seemed possible that the knowledge of this regular barometric see-saw would render possible forecasts for approaching seasons, its relation to rainfall was investigated.

Since rainfall, generally speaking, accompanies low pressure, the *inverted* pressure curves were compared with the rainfall curves for several stations. The very close relationship between the rainfall and inverted pressure curves which was thus found to exist suggested that there was a possibility of forecasting wet and dry years.

The problem becomes more difficult the further the equator is left behind and the poles approached, but it is thought that when further investigation has been made the behaviour of the pressure and consequently rainfall variations in these regions will be more completely known.

5. *The Relation between Solar Physics and Meteorology.* *By* Professor BIRKELAND.

6. *Experiments with Kites in the Mediterranean.* *By* L. TEISSERENC DE BORT.

7. *The Relation between the Minima and following Maxima of Sun-spots.* *By* ALFRED ANGOT.

Professor Wolfer published some time ago[1] a revision and continuation of R. Wolf's table of relative numbers of sun-spots, so we have now, for every month or year, the mean intensity of sun-spots from 1749 to 1901.

When working at that table in order to verify or find some periodicities I met with a relation that was not mentioned, so I presume it may be new.

'When the mean number of sun-spots during a year of minimum is *under* the average of all the minima, the value of the immediately following maximum is also *under* the average, and *vice versâ.*'

This will be apparent from the following table, which gives the relative numbers of sun-spots (r) during the years of minimum and the numbers (R) for the immediately following maxima, arranged according to the decreasing values of the minima. The numbers in brackets are the corresponding years:—

	r			R	
	11	[1766]		106	[1769]
	11	[1844]		124	[1848]
	10	[1784]		132	[1787]
	10	[1755]		86	[1761]
	9	[1833]		138	[1837]
	7	[1867]		139	[1870]
	7	[1775]		154	[1778]
	6	[1889]		85	[1893]
	4	[1856]		96	[1860]
	4	[1798]		48	[1804]
	3	[1878]		64	[1883]
	2	[1823]		71	[1830]
	0	[1810]		46	[1816]
Average	6·5		Average	99·2	

[1] *Astronom. Mittheil.*, No. 93.

With the exception of the fourth line, the first six minima, all above the average, are followed by maxima above the average, and the last six minima, under the average, are followed by maxima under the average. It seems even possible that the unique exceptions in the fourth line are only apparent, for it concerns the first cycle of observations (1755–1761), and it is not unnatural to believe that the scale with which the sun-spots were then evaluated was not exactly the same as it is now.

It would seem also that the interval of time between a minimum and the following maximum is smaller when the minimum is above the average and larger in the other case; but I believe this fact has been already mentioned.

If the relation indicated above holds true, we should be able to forecast one or two years in advance the general feature of a maximum of sun-spots from the observation of the preceding minimum. For instance, the last minimum (1902) has been very small; it seems probable that the next maximum will be rather late and under the average.

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8. *Relation between Pressure, Temperature, and Air Circulation in the South Atlantic Ocean. By* Commander C. Hepworth.

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9. *On the Ultra-red Absorption Spectrum of Ozone and the Existence of that Gas in the Atmosphere. By* Professor K. Ångström.

Already in 1861 Tyndall had found that, though oxygen transmits easily the radiation emitted from bodies of low temperature, this is by no means the case with its modification, ozone. In spite, however, of the evident importance of that discovery, it has not yet given rise to a more profound investigation of the character of this absorption. That question I have tried to solve by examining the spectrum of ozone from $\lambda = 0{\cdot}6\,\mu$ to $\lambda = 14\,\mu$ by means of the spectro-bolograph that I have constructed. The radiation was produced by a Nernst lamp of 110 volts. The absorption-tube, about 30 cm. in length, whose ends were closed by plates of rock salt, could be filled by 10 per cent. ozonised quite dry oxygen.

The result of that investigation is briefly the following:—

In the portion of the spectrum between $0{\cdot}6 - 4{\cdot}6\,\mu$, ozone does not seem to have any very considerable absorption-band, and as the radiation of the sun only in that part of the ultra-red spectrum has a greater intensity, it is evident that with regard to the quantitative absorption of solar radiation the ozone will not be of any greater importance. But in the following part of the spectrum ozone has several bands of great intensity, viz.:—

$\lambda = 4{\cdot}8\,\mu$	Sharp.
$\lambda = 5{\cdot}8\,\mu$	Weaker.
$\lambda = 6{\cdot}7\,\mu$	Uncertain.
$\lambda = 9{\cdot}1 - 10{\cdot}0\,\mu$	A very strong and extended band.

It is evident from the position, the intensity, and the extension of these bands that the radiation from sources of low temperature must be strongly absorbed by ozone. With the already mentioned absorption-tube I have examined the absorption of the integral radiation from the Nernst lamp as well as from a black surface at a temperature of 400°, 200°, and 100° C., and I have found it to be respectively

$$1^{\circ}{\cdot}8,\qquad 11^{\circ}{\cdot}1\qquad 13^{\circ}{\cdot}9,\quad \text{and } 16^{\circ}{\cdot}5.$$

The question arises then: Is ozone really one of the constituents in the atmosphere?

It is well known that the existence of ozone in the atmosphere—except after thunderstorms—has been doubted, and the chemical reactions for determining the quantity of ozone in the atmosphere are very uncertain. The knowledge of the

ultra-red spectrum of ozone offers us a means of solving that question. The solar spectrum below $\lambda = 4{\cdot}6\ \mu$ is certainly of little intensity and intersected by strong absorption-bands produced by aqueous vapour and carbonic acid; the solar radiation is, however, perceptible in all that space, and especially about $\lambda = 4{\cdot}8$ and $9{\cdot}5$ we know of no stronger absorption-bands caused by these gases. I have then, with the same spectrobolograph that I have used in the investigation of the absorption-spectrum of ozone at different times, registered the solar spectrum, and I have found that the band $\lambda = 4{\cdot}8$ as well as $\lambda = 9{\cdot}1 - 10{\cdot}0$ are present in the solar spectrum. During the month of March these absorption-bands in the solar spectrum were of about the same intensity as those I have found by using the absorption-tube, but in June they were much weaker, and the band $\lambda = 4{\cdot}8$ scarcely perceptible.

By this I have proved that—

1. Ozone produces a strong absorption in the ultra-red spectrum, where it is characterised by several bands of great intensity.
2. These bands are also present in the solar spectrum, where their intensity, however, is subjected to very great variations.
3. Ozone is then present in the atmosphere, and must exercise a strong but variable absorption on the radiation from the earth.

It is well known that sun-spots and the electrical phenomena in the terrestrial atmosphere are connected with one another. But it is also probable that these electrical phenomena are a cause of the production of ozone in the atmosphere, and consequently the absorption of the earth-atmosphere and the climate must to a certain degree depend on the sun-spots and vary with these.

It is evident that only continued investigations can teach us how much and in what manner the quantity of ozone varies in the atmosphere. For the moment I will here only insist on the importance of these investigations, for which the spectro-bolometer offers a very convenient method.

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10. *An Instrument for the Measurement of the Radiation from the Earth.* *By* Professor K. Ångström.

A question that has hitherto been but too little studied is the radiation from the earth. It is, however, of the greatest importance, not only as a climatological factor of great interest, but also for our knowledge of the influence of the atmosphere on the solar radiation.

Very interesting investigations in order to determine the radiation from the earth in absolute measures have been made by Pernter, Maurer, and Homén, and lately by Exner, who has employed for these examinations my pyrheliometer with electric compensation, but there is no doubt that the screen used in these researches in order to intercept the radiation from space introduces certain errors, and that a satisfactory instrument for determinating the radiation from the earth has not yet been constructed.

It seems, however, that a simple modification of my pyrheliometer with electric compensation would lead to a very good result, and the instrument which I have constructed according to that principle has, during the time in which I have had the opportunity to test it, proved itself to be a reliable and convenient one.

The modification of the pyrheliometer for that purpose consists only in exchanging the black strips of manganin for two platinum strips, *one black, the other bright.* These strips are placed beside each other in a little frame. Two thermo-elements are fastened to the back of these strips, and with a galvanometer it is possible to prove that the temperature of the strips is the same. The apparatus employed by the pyrheliometer are also used here, viz., a galvanic element, a rheostat to regulate the electric current, and an accurate amperemeter in order to determine the strength of current for heating the strips.

The frame is fastened at the upper end of a bright metallic cylinder, which before the beginning of the observations is closed by a cover. By exposing the

strips to radiation during the night, the black band is cooled more than the bright one, and in order to restore the equilibrium of the temperature it is necessary to conduct an electric current of certain intensity through the other.

The two strips being identical, excepting the difference in radiating power of the upper surfaces, we may easily find the value of the radiation w in question. The value of the electric current being i, the resistance of the strips per cm. m, the width b, the ratio between the radiating power C_1/c, we have:

$$W = \frac{\frac{m\, i^2}{4{,}18.6}{,}60}{1 - C_1/c}.$$

C_1/c can be determined very accurately in the laboratory once for all, and the not quite strict supposition that this quantity is a constant can be of no great consequence to the result, C_1/c being such a little quantity that a variation in it of 10 per cent. will only introduce an error of 1 per cent. in the results.

This instrument has, as will be easily understood, the same advantages as the pyrheliometer—that it is independent of the loss of heat through air-currents.

Among the questions which may be studied by means of this instrument I will mention the following:—(1) The variations of the radiation from the earth during the night and during the year; (2) the connection between this radiation and the quantity of humidity, ozone, and carbonic acid contained in the air; (3) the connection between the absorption of solar radiation and the radiation from the earth.

Department of Mathematics.

The following Papers and Reports were read:—

1. *The Law of Error.* *By* Professor F. Y. Edgeworth, *D.C.L.*

The approximate expression for the frequency with which different values are assumed by a quantity that depends on a great number of independently varying elements is investigated by a new method: corroborating the first and second approximations, which had already been obtained, and obtaining the third, fourth, and, generally, the t^{th} approximations. The results are extended to the case in which the elements fluctuate in several dimensions, and to the case in which the compound is a function other than linear of the elements, a function capable of expansion in powers of the elements, which are *not* neglected.

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2. *Report on the Theory of Point-groups.*—Part IV. *By* Frances Hardcastle.—See Reports, p. 20.

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3. *Notes on Plane Curves.* *By* Harold Hilton, *M.A.*

The effect of an ordinary multiple point of the k-th order with superlinear branches of orders $r, s, t, \ldots$ on the class, deficiency, and number of inflexions of a curve is the same as the effect of $\{\frac{1}{2}k(k-1) - \Sigma(r-1)\}$ nodes and $\Sigma(r-1)$ cusps.

The number of conics through four fixed points touching a curve is $2n+m$): the harmonic envelopes of any fixed conic j and $(3n+\iota)$ conics passing through two fixed points on j and osculating the curve (or $\frac{1}{2}[4n^2 + 4nm + m^2 - 4n - 10m - 3\kappa]$ conics passing through two fixed points on j and having double contact with the curve) are degenerate. The number of conics through two fixed points having

double contact with a fixed conic and touching the curve is $2(n+m)$: the number of conics through a fixed point having double contact with a fixed conic and osculating the curve is $2(3n+\iota)$, &c.

The intersections of the other circular lines through the intersections of a curve with the circular lines through any point A (the satellites of A) play an important part in the theory of curves, especially when A is a focus. For example:—At bicircular quartics through four fixed points, A, B, C, D, having B as a focus whose satellite is A, pass through a fifth fixed point and have four-point contain with the osculating circle at A.

The locus of the vertices of the common self-conjugate triangle of any osculating conic through two fixed points and of a fixed conic through these two points is of degree $2(3n+\iota)$, class $2(2n+4m+\kappa)$, and has $2(11n+3\iota)$ inflexions. This is an extension of the theory of evolutes.

The r-th positive pedal of a curve is of degree $2(r-1)n+2rm$, class $rn+(r+1)m$, and has $(3n+\iota)$ inflexions, &c., &c. $(r>1)$. Since the r-th negative pedal of a curve is the inverse of the r-th positive pedal of the inverse curve, we can readily deduce the properties of negative pedals from those of positive pedals.

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4. *Note on a Special Homographic Transformation of Screw System* *By* Sir ROBERT BALL, *LL.D., F.R.S.*

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5. *The Theory of Vibrations.* *By* Professor V. VOLTERRA.

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6. *The Stability of the Steady Motion of a Viscous Fluid.* *By* Professor W. McF. ORR.

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7. *Note on the Schwarzian Derivative.* *By* Professor A. C. DIXON, *F.R.S.*

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8. *Note on the Theory of Continuous Groups.* *By* Professor A. R. FORSYTH, *F.R.S.*

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9. *Some Observations on Linear Difference Equations.* *By* Rev. E. W. BARNES.

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10. *On the Use of Divergent Series in Astronomy.* *By* Z. U. AHMAD.

MONDAY, AUGUST 22.

The following Papers and Reports were read:—

1. *Recent Improvements in the Diffraction Process of Colour Photography.* *By* Professor R. W. WOOD.

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2. *On 'Reststrahlen' and the Optical Qualities of Metals.* *By* Professor H. Rubens.

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3. *On the Separation of the Finest Spectral Lines.* *By* Dr. O. Lummer.

By the realisation of the black body and the experimental work during recent years on the black radiation our knowledge of the radiation laws has reached a certain point of completion. The constant of Kirchhoff's law is as well known now for every wave length and every temperature as is necessary for any practical purpose. Having determined experimentally the laws of black radiation up to 2,500° C., Pringsheim and I are now bringing in the radiation temperature scale based on these laws. The most important work now seems to me the study of the radiation from all bodies, especially gases, whether they conform to Kirchhoff's law or not. To answer this promising question we must, in my opinion, study from the beginning the mechanism of gas radiation itself—energy distribution. These spectra consisting mostly of narrow lines, we must resolve these lines still further if we would draw conclusions about the existing mechanism.

Led by these considerations, I began to work on the modern apparatus of high resolution, and I have brought with me the interference spectroscope, which, based on the interference fringes of a parallel glass plate, I worked out with Dr. Gehrcke; I am, therefore, able to show you its effect on the spectral lines produced by a mercury-lamp.

In our recent paper, published in the Reports of the German Physical Reichsanstalt, we gave the general theory of all apparatus of high revolving power, including the prism spectroscope, the grating, the Michelson echelon spectroscope, the interference spectroscope of Perot-Faby, and our own.

Since the brilliant discovery of Zeeman we know the importance of apparatus with high resolution. Therefore, if we go further and put up apparatus of higher resolution, why should we not observe also the moving *positive* electrons, if they can by any means be excited so as to produce light energy? And if the action of the *electric* field on the light is too small to be detected now, perhaps an apparatus of higher resolution may be able to do so. Be that as it may, only an apparatus of the highest resolving power can help us to enter into the molecule itself and give us new pictures of occurrences in the interior of an atom. Only by the aid of the most complete separation can we find the differences in the spectra of the so-called 'homogeneous' spectral lines, when, for example, we raise the temperature of a radiant gas, or change the manner of exciting the electrons, using electric waves of a high or low period.

Working in that direction with our interference spectroscope (demonstrated in the Cavendish Laboratory) we got some results which seem to us interesting, in so far as they show that vacuum tubes filled with mercury, hydrogen, sodium, helium, and argon, excited by Hertzian electric waves, give less well-defined interference maxima than when excited by the induction coil. Discussing these unexpected phenomena, we are of the opinion that this loss of sharpness is not a consequence of the Doppler principle for several reasons; for example, because the intensity with Hertzian waves as the cause of luminosity is less than with the induction coil. We incline to believe that the Hertzian waves will enlarge the number of the many satellites of which, in our opinion, every line consists. Surely we can conclude that the excitement in a vacuum tube is not the result of heat, but of electrical occurrences.

In my introduction I pointed out what important consequences this result has, in so far as we are not allowed to use Kirchhoff's law for luminous bodies giving line-spectres, nor to draw conclusions from the brilliancy of these lines as to the temperature of the luminous gas.

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4. *Recent Work at the National Physical Laboratory.* *By* Dr. R. T. Glazebrook, *F.R.S.*

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5. *An Effect of Electrical Vibrations in an Optically Active Medium.* *By* Professor W. VOIGT.

Optically active isotropic bodies, which I propose to call *pseudo*-isotropic bodies, differ in their physical symmetry from the ordinary or real isotropic bodies by opposite directions of rotation being not equivalent. In the case of regular crystals, which in many respects show themselves to be physically isotropic, this difference is expressed in the crystalline form; in the case of isotropic bodies the phenomenon proving the pseudo-isotropic nature is that the right-handed and left-handed circularly polarised waves are propagated with different velocities.

Compared with the real isotropic, the pseudo-isotropic bodies exhibit a peculiar property as regards the action of vector fields upon them. In *real* isotropic media a field of either polar or axial character always establishes a parallel field of the *same* character; for example, an electric force establishes a parallel electric moment, a magnetic force a parallel magnetic moment. In *pseudo*-isotropic media, on the other hand, an *axial* field can establish a *polar* field, and *vice versâ*.

These symmetric relations have been put to account, though without a definite knowledge of that general and fundamental law, in the trials made to deduce theoretically the laws of optical activity, whereby the components of a *polar* vector always were combined additively in the usual differential equations with the parallel components of an *axial* vector; for example, with the parallel components of the curl or of the rotation of this polar vector.

Such procedure has, however, hitherto furnished no results other than the mere laws of the singular optical phenomena for the deduction of which it was conceived. But it is still highly probable that the pseudo-isotropic bodies differ physically from the real isotropic bodies also in other ways than their optical properties.

I wish to speak to-day of an electro-magnetic action in the proper sense of this term, which is indicated by the equations of the electro-magnetic theory of optical activity, and with the experimental realisation of which I have busied myself within the past few months.

The optical equations for the pseudo-isotropic media which I have proposed, and which Professor Drude also subsequently established, with the help of a special conception of the motion of electrons, are as follows:

If $\mathfrak{E}$ be the electric force,
$\mathfrak{H}$ „ „ magnetic force,
$\mathfrak{K}$ „ „ electric polarisation,
$\mathfrak{L}$ „ „ magnetic polarisation,

then, according to Maxwell and Hertz,

$$\dot{\mathfrak{K}} = c \operatorname{rot} \mathfrak{H}, \quad \dot{\mathfrak{L}} = -c \operatorname{rot} \mathfrak{E},$$

and I put

$$\mathfrak{K} = \mathfrak{E} + \Sigma x, \quad \mathfrak{L} = \mathfrak{H} + \Sigma \frac{d}{e} \dot{x}$$

$$x + a\dot{x} + b\ddot{x} + c\mathfrak{H} = e\mathfrak{E},$$

where $x_1, x_2, \ldots$ is a system of polar vectors and a, b, c, e are constants individual to these vectors.

The last formula expresses by the combination of $\mathfrak{H}$ and $\mathfrak{E}$ that, *in the pseudo-isotropic media, the electric vibrations excite parallel magnetic vibrations.*

For deducing by theory an observable electro-magnetic effect the following problem may be considered:—

Let infinite space be filled with a system of standing plane electric waves, the wave surface being parallel to the Y f plane and the electric force parallel to the f axis. In one of the loops of these standing waves let a sphere be cut from some pseudo-isotropic medium. The diameter being small in comparison with the length of the waves, the sphere is always in a homogeneous field whose strength varies periodically.

If the sphere were cut from some *real* isotropic substance it would under these conditions send out electric vibrations whose directions lie exclusively in planes which pass through the f axis—that is, in *meridian planes*, and which are connected with magnetic vibrations perpendicular to this plane. But since the sphere is pseudo-isotropic it also sends out rotational electric vibrations around the f axis, *perpendicular* to the meridian planes, connected with magnetic vibrations *in* the meridian planes.

The presence of these circular electrical vibrations may be experimentally demonstrated if we surround the sphere with a flat coil of wire, placed in the equatorial plane and connected with a detector of sufficient sensibility.

For a point of the equator the circular electric force has a comparatively simple value. Let ν be the difference between the indices of refraction for sodium light of the two circularly polarised waves propagated within the medium, and κ be the ordinary dielectric constant of the medium; let λ be the wave length in empty space of the electric vibrations amongst which the sphere is placed, T_s/T the ratio of the periods of sodium light and of the electric waves employed; R the radius of the sphere, and Z the amplitude of the existing electric vibrations. Then, in an allowed approximation, the amplitude T of the circular electric force is given by

$$P=\nu \cdot \frac{T}{T} \cdot \frac{R}{\lambda} \cdot \frac{K}{K+2} \cdot f.$$

Since ν as well as T_s/T and R/λ are small, the coefficient of f is *very* small, and observations about the calculated effect may be made only in a *qualitative* way. I used a regularly formed piece of *quartz*, which was allowed with certain restrictions to be taken as a sphere of a pseudo-isotropic medium. I had R nearly 4 cm., $f=4000$ volts, $\lambda=100$ m. and a coil of 200 turns. In these conditions an electromotive force of about 10^{-8} volt in the coil was to be suspected. This is a very weak effort, which can be easily cloaked by other vibrations which affect the detector; for instance, by those coming directly from the electric oscillator.

In some cases it was possible to make the disturbing effects very small, and to observe an electric vibration similar to that suspected; for the most part, however, the results were doubtful. I shall, therefore, have to lay more stress upon the interesting indications of theory than upon the results of observation.

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6. *Discussion on* N-*Rays.* *Opened by* Dr. O. Lummer.

Having been asked by the Committee to open a discussion on the N-rays, I gave a short account of the experiments which Professor Rubens and I had carried out on this curious subject. We had worked hard to detect them, but had absolutely failed, both in the direction of photographic effect with the spark and of subjective observation. We made besides photometrical experiments, not previously carried out, which showed that, observing in the dark a faintly luminous screen indirectly, with a well-adapted eye, the difference of intensity must be changed at least 30 per cent. to give a perceptible effect. On the other hand, the change from direct to indirect vision increases the intensity from one to four and more, due to the fact that we observe directly with the cones of our retina, indirectly with the rods.

But also in the case of continued indirect vision, which the N-ray observers maintain to be necessary, physiological processes go on in the eye which give great variability of the luminosity of such small phosphorescent screens, one of which I described under the title of the 'Heinrich-Phenomenon.' All our experiments, therefore, confirmed our opinion that all such effects, including the newest experiments of Jean Becquerel, were to be attributed to physiological causes.

Mr. Butler Burke, of the Cavendish Laboratory, gave an account of his experiments with a view to obtaining evidence as to the nature of this new, and it might

almost be said, mysterious radiation. But as to the photography of the action of N-rays on a small spark it would appear from Mr. Burke's results that the effects obtained by M. Blondlot are due to the influence of the screens employed in increasing the capacity of the apparatus and thereby diminishing the brightness of the spark. Mr. Burke had already pointed this out in the course of his correspondence on the subject in 'Nature' during the last few months. He next summarised the evidence of direct observation of luminous sources, and stated that in the course of his experiments he had tried the vision of numerous persons, but that in no case was there satisfactory evidence of any external action upon the sight. Mr. Burke then entered into the particulars given in M. Blondlot's paper on the wave-lengths, and emphasised the fact that the arrangements were such that unless the energy of the N-rays is enormously greater than that of the luminosity from the same source, it would be absolutely impossible to observe the diffraction fringes, the energy being reduced to about $\frac{1}{8000}$th of the original in the arrangements employed. He then pointed out that the determinations of the velocity of Röntgen rays and their polarisation would have to be reconsidered unless it can be shown that Röntgen rays produce the increased brightness of the spark which the N-rays were supposed to do.

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7. *Standards of Wave Length.*[1] *By* Professor KAYSER.

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8. *Report of the Committee on Electrical Standards.* See Reports, p. 30.

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9. *Exhibition of a Magnetic Alloy containing no Iron.* *By* R. A. HADFIELD.

SUB-SECTION OF ASTRONOMY AND COSMICAL PHYSICS.

The following Papers and Reports were read:—

1. *Report of the Seismological Committee.*—See Reports, p. 41.

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2. *Report on the Investigation of the Upper Atmosphere by means of Kites.*—See Reports, p. 17.

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3. *The Temperature of the Air in Cyclones and Anticyclones, as shown by Kite-flights at Blue Hill Observatory, U.S.A.* *By* A. LAWRENCE ROTCH, *B.S., M.A.*

This paper gave an account of an investigation of which the preliminary results were presented to the sub-section last year. The data for fourteen kite-flights, made at different seasons and in areas of high and low barometric pressure, were combined with the data previously obtained, and the mean changes of temperature, by stages of 500 metres (1,600 feet), have been determined up to an altitude of about 12,000 feet. The decrease of temperature with the increase of height is nearly uniform and is practically the same for both low and high pressures, amounting to 0°·86 Fahr. per 100 metres in the former condition, and 0°·88 Fahr. per 100 metres in the latter, or 1° Fahr. per 381 feet and 370 feet respectively. This

[1] Published in the *Phil. Mag.*, viii. p. 568 (1904).

relatively slow decrease, as compared with the adiabatic rate, is due to the frequent inversions of temperature occurring at all heights in the free air. Whether the whole column of air in a cyclone is, on the average, warmer than that in the anticyclone depends chiefly upon whether its initial temperature at the ground is higher, as is usually the case when cyclonic conditions prevail in our latitudes. A more conclusive method of investigation is to plot the temperatures at the same heights in the free air during several consecutive days, when the barometric pressure and the air-temperature vary at the ground. This appears to have been done first by H. H. Clayton, meteorologist at Blue Hill, who utilised the daily kite-flights made there,[1] one conclusion being that the maximum air-temperature at all heights (up to 12,000 feet) nearly coincides with, but slightly precedes the minimum of atmospheric pressure at sea-level, and that the minimum air-temperature at the different heights apparently occurs when the atmospheric pressure at sea-level is above normal, but usually some distance in advance of the maximum of atmospheric pressure there. Mr. Clayton now finds that the air in contact with mountain summits is colder than is the free air at the same height, which tends to invalidate the arguments against the convectional theory of cyclone-formation, based upon mountain observations.

Kite-flights on Blue Hill are generally made once a month upon the days prescribed by the International Committee for Scientific Aeronautics. During 1903 there were fifteen flights, the average of the highest points reached in each flight being 7,264 feet above sea-level, and the maximum height in any flight 13,970 feet. During the present year, from January to July inclusive, the nine flights have given an average height of 8,284 feet and a maximum of 14,660 feet. During the present summer, the writer hopes, by means of *ballons sondes,* liberated from St. Louis, to extend the observations of temperature in the free air to a height never before attained above the American continent.

4. *Problems of Astronomy.* *By* Sir DAVID GILL, *K.C.B., F.R.S.*

5. *Discussion on Units used in Meteorological Measurement.* *Opened by* Dr. W. N. SHAW, *F.R.S.*

6. *On the Masses of the Stars.* *By* Dr. H. N. RUSSELL.

TUESDAY, AUGUST 23.

The following Papers were read :—

1. *A Correlation between the Electric Conductivity of Air and the Variation of Barometric Pressure.* *By* JOHN DON, *M.A., B.Sc.*

From their experiments already described in the 'Annalen der Physik' and elsewhere, Professors Elster and Geitel have shown that an insulated electrified conductor, in free air, undergoes a loss of charge which is to be attributed only in a small measure to imperfect insulation on the part of the supports.

The rate of loss was found to vary according to the state of the weather, being *increased* by bright sunshine, by winds from hilly districts and by low atmospheric pressure, while it was *diminished* by fog and rain and cloud, and by the presence of dust and soot in the air.

In a contribution to the 'Archives de Science' of Geneva, in January 1904

[1] See Blue Hill Observatory *Bulletins,* No. 1, 1899; and No. 1, 1900.

these observers describe the results of their investigations with regard to the effect of the soil upon the loss of electrification in a neighbouring charged conductor. They had previously been led to the conclusion that the conductivity of the air is due to the presence of free ions, and the object of their research was to discover the source from which free ions arose. That they might proceed from the surface of the ground under suitable conditions there was no reason to doubt.

In the case of certain calcareous soils, the conductivity of the adjoining air was very remarkable, and, in general, air which had been for a time in immediate contact with soil acquired increased conductivity.

Partly for the purpose of repeating these experiments, which had attracted attention abroad, and in part for the purpose of discovering the nature of the relation between the conductivity of the air and the principal atmospheric phenomena, a series of daily observations was made on the East Coast of Aberdeenshire from January to May of the present year. A statement of some part of the observations recorded, together with a description of the instruments employed, has already been published ('Elec. Review,' March and April 1904).

It was, however, at the conclusion of an extended series of experiments that it became possible to ascertain whether, and to what extent, correlations existed. It is believed that the present series is one of the first that has been made in this country, while it is probably the largest yet attempted anywhere.

The number of observations is sufficiently great to ensure a tolerably reliable result from the application of the methods of reckoning correlation. More especially is this so, because each experiment was checked by two observers, and repeated if any doubt arose.

During the first five months of the year great variety of weather conditions was experienced.

The daily experiment consisted in aspirating a measured volume of air over the leaves of a specially constructed electroscope which had been charged to a certain potential. Any leakage on the part of the insulators was first measured and subsequently allowed for.

An illustrated description of the apparatus originally employed, and afterwards somewhat improved, will be found in the 'Elec. Review,' March 1904. In the improved form of electroscope the leaves are unequal in size, so that the heavier one hardly moves when a small charge is imparted. Both leaves are suspended by the finest and best silk fibres over a diaphragm, which concentrates the current of aspirated air upon them.

Now it was evident as the experiments proceeded that some relation existed between the height of the barometer and the conductivity of the atmosphere, but yet on several occasions the electroscope showed insignificant loss of charge, not only when the pressure was high but also when it was low. Further, in such cases the barometer was, as a rule, steady for a time. To this there were some exceptions. On the contrary, a greater fall of potential had from time to time been observed when the barometer was falling than when it was rising, and this occurred both with high and with low pressures.

Hence it seemed almost likely that the conductivity of the air was dependent on the variation of barometric pressure. A calculation was accordingly made (following generally Professor Karl Pearson's long method), and it resulted in the discovery of this fact, that the conductivity of the air is increased by a fall of pressure, and is correlated with daily variations of pressure to the extent of 37·4 per cent.

In the subjoined table the fall of the leaves of the electroscope (which were charged on the average to a divergence of about 1 cm.) is stated on the horizontal columns in 100ths of a mm. per tenth of cubic foot of air aspirated.

The rise or fall of the barometer during the day preceding an observation is stated in twentieths of an inch on the vertical columns.

The mean fall of the leaves for 114 observations was 11·26 hundredths of a mm., and the S.D. for the series 11·73.

The mean variation of pressure for the period was almost exactly zero, and the S.D. was 4·68.

35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Totals
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																0
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—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	1	13
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—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	5
—	—	—	—	—	1											5
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																0
0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	4	Totals
		26·74			28·74					33·74					38·74	Distances of Variates from Mean

if any) for $\frac{1}{10}$ cub. ft. of air drawn.

Correlation Table showing Variation of Pressure and Conductivity of Air

Totals: 4 14 2 3 2 4 8 5 9 6 3 13 | 2 2 1 3 7 | 0 1 1 1 5 | 0 | 0 2 0 2 [illegible] 1 0 0 4 | 0 1 | 0 0 0 0 1 0 0 1 | 0 0 0 0 1 0 0 0 | 0 4

Distances of Variates from Mean: 11·26 10·26 9·26 8·26 7·26 6·26 5·26 4·26 3·26 2·26 1·26 ·26 ·74 1·74 2·74 3·74 4·74 5·74 6·74 7·74 8·74 9·74 10·74 11·74 12·74 13·74 14·74 15·74 16·74 17·74 18·74 20·74 26·74 28·74 33·74 38·74

$\sigma_2 = 11·73$

* Unit is [illegible] inch rise or fall of barometer during previous day.

† Unit is [illegible] th. cm. fall after [illegible] electrometer for [illegible] cub. ft. of air drawn.

The greatest rise of the barometer observed for twenty-four hours was ·65 in. and the greatest fall ·6.

The fall of the leaves was zero on eighteen occasions, while it was as much as ·5 mm. on four days. All the observations here given refer to a negative charge.

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2. *On the Ionisation of the Atmosphere. By* Professor A. Schuster, *F.R.S.*

I have recently described[1] an instrument which allows us to obtain data for the measurement of the number of ions formed in unit time in atmospheric air. A number of observations have now been made which have led to an improvement in the apparatus and given some interesting results. The two data used for the determination are:

(1) The number of ions, determined as in Ebert's well-known apparatus; and
(2) The measurement of the rate of recombination of ions.

An improvement has been effected in Ebert's apparatus by shortening the length of the tube and the rod, so as to reduce its capacity to about 6·4 electrostatic units. This shortens the time in which an observation can be carried out from a quarter of an hour to about five minutes. The electroscope in the form now used by me is placed above the cylinder instead of below, which much lessens the deposit of dust on the insulating material and thus preserves it.

The leak which always takes place when the apparatus is closed, and which is partly due to the leak of supports and partly to the continuous ionisation which takes place in confined air, was observed to be much increased whenever the apparatus was taken out of doors on a clear day. This effect was ultimately traced to convection currents in the apparatus, but the manner in which these currents act has not yet been ascertained. So far as my observations allow me to judge, they suggest the existence in the air of very slow-moving ions, which only give up their charges when they are brought into contact with metallic conductors.

The observations made on Exmoor, at a height of 1,400 feet, have led to the conclusion that the state of the air, as regards its power to allow ions to recombine, varies sometimes with great rapidity, especially near the time of sunset. The air on Exmoor was found to be very pure, so as to give a slow rate of recombination. On the other hand, the number of ions in general was rather less than that found near the level of the sea. Combining these results, I come to the conclusion that the number of ions found on Exmoor during the time the observations were made was considerably less than that commonly observed at lower levels.

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3. *Discussion on the Radio-activity of Ordinary Matter. Opened by* Professor J. J. Thomson, *F.R.S.*

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4. *On the Radio-activity of the Hot Springs of Aix-les-Bains. By* Dr. G. A. Blanc.

A research concerning the radio-activity of both the thermal waters of Aix-les-Bains was made by me recently. Their temperatures are respectively 47° and 44° Centigrade. They both belong to the sulphur soda class.

The fact which I principally wish to point out is the strong ionisation of the air inside the grotto where one of the springs is situated. Measures by means of an Elster and Geitel electroscope, surrounded by a wire netting, showed that its conductivity was about sixty times greater than that of the air outside; 1·75 lit. water of this same spring gave to 5 lit. air that had been repeatedly bubbled through it a conductivity rising to over 200 times the normal. The other spring's

[1] *Manchester Memoirs* vol. xlviii., No. 12 (1904).

water only caused a thirtyfold increase, while that due to ordinary Chambéry tap water was of only fifteen times the normal value. The maximum of effect was reached after half an hour's bubbling.

The most active sediments which I could get (being collected only at a certain distance from the actual source) showed activity comparable to that of the fanghi of Battaglia and the sediments of Bad Nauheim, tested by Elster and Geitel.

A viscous matter, partly organic, called Barégine, which floats on the water, showed the strongest activity; it is to be noted that this substance is formed at the spot where the waters emerge from the rock, and is then carried away by them as it floats.

A great amount of emanation was obtained by repeatedly drawing air through some heated sediment; its activity decayed according to an exponential law, falling to half its value in 3·2 days. The same result was given by emanation obtained by bubbling air through the waters.

A disc of tinfoil charged at -600 volts and kept in a metal vessel containing some 100 gr. sediment showed excited activity, the rate of decay of which has not yet been precisely determined.

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5. *Plan of a Combination of Atoms having the Properties of Polonium or Radium.*[1] *By* Lord KELVIN, *F.R.S.*

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6. *Electrical Insulation in Vacuum.*[2] *By* Lord KELVIN, *F.R.S.*

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7. *Electrical Conductivity of Flames.* *By* Dr. H. A. WILSON.

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8. *The Electrical Properties of Hot Bodies.* *By* Dr. O. W. RICHARDSON, *M.A.*

In every case of steady ionisation by hot bodies which has been examined up to the present, the quantity of electricity C discharged in unit time is connected with the temperature θ by the relation $C = A\theta^p e^{-b/\theta}$. In this formula A and b are constants which depend on the nature of the body and on the state of its surface, and are different for positive and negative electricity. The numeric p also is a constant which does not vary sufficiently from zero to cause the variation of θ^p with θ to be comparable with that of the exponential term.

In cases like that of the negative leak from hot metals, where the ionisation in a good vacuum is a steady function of the temperature alone, a formula of this type can be deduced thermo-dynamically. The only assumption made in the proof is that the phenomenon is reversible, *i.e.*, that the ions given off behave like a vapour, and can be in equilibrium with the metal at a definite pressure. Deduced in this way the formula for the quantity of negative electricity given off by hot bodies is found to be $A\theta^{\frac{1}{2}}e^{-b/\theta}$. This formula has been verified by the author[3] for the cases of platinum, carbon, and sodium. Wehnelt,[4] who found that the negative leak from hot platinum was greatly increased by covering the surface with the oxides of barium, strontium, and calcium, showed that the same law held for the discharge from these substances, whilst more recently Owen[5] has found a similar relation for the negative leak from a Nernst filament.

The case of the positive leak from hot substances is essentially different from that of the negative. Here the current is not a steady function of the temperature, but decays asymptotically with time at constant temperature. The rate of

[1] Printed in full in *Phil. Mag.*, vol. viii. p. 528 (1904).
[2] Printed in full in *Phil. Mag.*, vol. viii. p. 534 (1904).
[3] *Phil. Trans.*, A., vol. cci. p. 497.
[4] *Drude's Ann.*, vol. xiv. p. 425.
[5] *Phil. Mag.*, VI., vol. viii. p. 230.

decay has been found to increase rapidly with the temperature, so that at low enough temperatures the rate of decay is inappreciable, and the leak appears to be a definite function of the temperature of the wire. In these cases, where the amount of the positive leak does not decrease perceptibly during the course of the experiments, it also is found to obey the above formula. This is found to be the case on reducing the observations given by Strutt[1] for the positive leak from silver and copper in air and silver and copper oxide in hydrogen between the temperature limits of 175° C. and 331° C., and has been fully confirmed by a large series of numbers obtained by the author in investigating the emissibility imparted to a platinum wire by the luminous discharge. It also holds for the numbers given by Wehnelt[2] for the positive leak from the alkaline earths, and those given by Owen[3] for the positive leak from the Nernst filament. Generally speaking, the numbers given for the positive leak are not so accurate as those for the negative, owing to the complication caused by the falling off with time; and as we have no theoretical guidance here, we cannot be certain that in this case the index p in the formula $A\theta^p e^{-b/\theta}$ is equal to one-half.

None of the results for the ionisation from hot bodies appear to be in disagreement with this formula. It holds for all temperatures where the ionisation is a definite function of the temperature, and its applicability extends over a far wider range than those cases where it can be shown to hold theoretically. In cases where the thermodynamic reasoning applies, the quantity b has a definite meaning, and is equal to twice the energy in calories required to set free a gram molecular weight of the ions from the hot substance. As to its magnitude, $b/2$ is always of the order 10^5, and varies from $2{\cdot}67 \times 10^4$ for the positive leak from silver in air (Strutt, *loc. cit.*) to $1{\cdot}32 \times 10^5$ calories for the negative leak from hot platinum (H. A. Wilson, 'Phil. Trans.,' A., vol. cxcvii. p. 415).

It is not without significance that the rate of production of ions by hot substances is connected with temperature by the same formula as that which expresses the temperature variation of the velocity constant of almost all known chemical reactions.

9. *The Production of Radio-active Surfaces.* *By* C. E. S. PHILLIPS.

The opacity of radium bromide to its own radiations (and especially to the X-rays) makes it necessary, in order to get the greatest action from a specimen, that the material should be spread evenly over a considerable surface. And, in addition, it has been thought advisable to find some means of distributing the radium upon a surface capable of ready sterilisation, so that, after its application for therapeutic purposes, it may be rendered completely innocuous. The following method has been found to be rapid and effective.

A short length of platinum wire was coated with a layer of radio-active crystals by dipping it into a concentrated solution of radium bromide, and after drying over a flame this wire was sealed into a long straight vacuum tube. A cylinder of thin mica was then slipped into the tube, so that the wire stood axially within it. Having sealed a second wire (to serve as anode) into the tube, the apparatus was exhausted, while the radium-coated electrode remained connected with the negative terminal of an induction coil. The passage of the discharge deposited in a few moments a fairly uniform radio-active metallic layer upon the mica. A surface so prepared may be cleansed without diminishing its radio-active properties by raising it momentarily to a red heat, and appears to be a suitable means of applying comparatively small quantities of radium for therapeutic or other uses where a considerable area is required to be radiated.

10. *The Kinetic Theory: Determination of the Size of Molecules.* *By* J. H. JEANS.

[1] *Phil. Mag.*, VI., vol. iv. p. 98 [2] *Loc. cit.* [3] *Loc. cit.*

11. *Dr. Grindley's Experiments on Steam in the Light of the Ether-pressure Theory.* By J. Macfarlane Gray.

Newton regarded the pressure of the ether as very great, and sufficient, by its slope, to account for terrestrial and stellar gravitation. Ether-pressure cannot be selective; if it acts upon stars it must also press upon every atom of matter and be the most important of all natural forces, and the fundamental factor in every physical phenomenon. Neothermodynamics therefore begins with ether-pressure as in equilibrium with every other pressure, whether of solids, liquids, or gases. The play space of every contributory molecule of gas, as its amplitude of vibration was acquired, from absolute zero temperature—even if in an envelope of constant volume—must have been obtained by driving back the ether, and, just as external work is pv, so this internal work is also pv. The translation energy of gas is $1\frac{1}{2}$ times its pv; or, the constitutional energy of a gas exclusive of external work is $2\frac{1}{2}\,pv$. Including the external pv, the total energy from absolute zero is $3\frac{1}{2}\,pv$, and the ratio is 1·4. By this reasoning the same ratio must hold good for all gases.

This paper was an examination of Dr. Grindley's important experiments in the light of this ether-pressure theory.

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12. *On a Volatile Product of the Radium Emanation.* By W. C. D. Whetham, *F.R.S.*

Some months ago the writer and his wife found that the excited activity deposited on solid surfaces by the emanation from pitchblende was partially due to a substance volatile at ordinary temperatures.

A similar result has now been obtained by the use of the emanation from radium bromide. On blowing out the emanation from a vessel in which it has stood, the walls of the vessel will be found to slowly yield a radio-active substance which diffuses into the air within the vessel.

Experiments are being carried on to determine the rate of radio-active change of this substance and to investigate its other properties.

Whether this product is identical with that announced by Miss Brooks ('Nature,' July 21, 1904) remains to be determined.

WEDNESDAY, AUGUST 24.

Department of Physics.

The following Papers were read:—

1. *The Propagation of Electric Waves along Spiral Wires, and on an Appliance for Measuring the Length of Waves used in Wireless Telegraphy.*[1] By J. A. Fleming, *M.A., D.Sc., F.R.S.*

This paper was concerned with an experimental and theoretical treatment of the propagation of electric waves along spiral wires.

The subject has engaged the attention of several physicists. Hertz has described an experiment in which he established stationary electric waves on a spiral wire and compared the distance of the nodes with the corresponding distances when the wire was stretched out straight.

Theoretical treatment has been given by H. C. Pocklington, and G. Siebt has devised lecture apparatus for exhibiting the propagation of stationary waves on spiral wires.

The first experiments described by the author were made with a long helix of

[1] Printed in full in *Phil. Mag.*, vol. viii. p. 417 (1904).

insulated copper wire, wound in one layer on a wooden rod. The helix consisted of 5,000 turns, the length being 200 centimetres. If such a helix is placed in connection with an oscillating circuit consisting of a condenser or Leyden jar, a spark gap and a variable inductance, stationary waves could be set up on the helix by adjusting the inductance in the oscillating circuit. In order to detect the nodes and antinodes of these stationary oscillations, the author makes use of a vacuum tube, similar to that used in spectrum analysis, preferably one filled with the rare gas, Neon, which was kindly supplied to him by Sir William Ramsay. Rarefied Neon seems to be extremely sensitive to the presence of variable electric force through it; hence, if such a tube is held perpendicular to the helix and moved parallel to itself along it, it glows brightly at the antinodes but not at the nodes. In this manner the internodal distances can be measured with considerable accuracy, and the wave-length of the stationary oscillation measured.

The paper also contained a theoretical analysis of the phenomena leading to the conclusion that the velocity with which the wave is propagated along the spiral is inversely proportional to the square rood of the product of the capacity and inductance of the helix per unit of length. The author has perfected of late years methods for measuring very small capacities and inductances, and in the case of the above-named helix the inductance is equal to 100,000 centimetres per centimetre, whilst a capacity of the helix is $\frac{7}{40}$ of a micro-microfarad (1 micro-microfarad $=10^{-6}$ microfarad).

From these data the velocity of propagation of electric waves along the helix can be shown to be 235,000,000 centimetres per second. This figure is confirmed in the following manner: The capacity and the inductance in the oscillating circuit are both measured when the first harmonic oscillation is formed on the helix, and under those conditions the half wave-length was found to be 140 centimetres, whilst the frequency in the oscillating circuit, as calculated from the capacity and inductance, was found to be $0{\cdot}847 \times 10^6$.

Having, therefore, the wave-length and frequency, we find their product gives a velocity of 235,000,000 centimetres per second, which agrees with the figure determined from the constants of the helix.

It was shown that the best form of inductance to be employed in connection with the oscillating circuit is a square of one turn of wire, and that the employment of spiral coils leads to errors due to passage of a dielectric current from coil to coil. On the above lines an apparatus has been devised by the author for measuring wave-lengths in connection with Hertzian wave wireless telegraphy. It is a matter of considerable importance to be able to determine the frequency and wave-length of the waves sent out by any given transmitting arrangement.

The author calls this instrument a 'Kummeter.' It is constructed as follows: A long ebonite rod is wound over closely with silk-covered wire in one layer, and this is supported on insulating stands. On this long helix slides a metal saddle having some layers of tinfoil interposed to make good contact between the saddle and the helix. This saddle is connected by a flexible wire with the earth. One end of the helix is furnished with an insulated metal plate, which is placed in apposition to another metal plate connected to the oscillating circuit of the transmitter. The process of measuring the wave consists in sliding the saddle along until a Neon vacuum tube indicates the presence of one node halfway between the saddle and the plate. When this is the case the distance from saddle to plate is one wave-length of the stationary wave on the helix.

From the constants of the helix the velocity of the wave along it can be calculated as above shown, and hence the frequency of the oscillating circuit becomes known. If this frequency is divided into the velocity of light, reckoned in feet, it gives the wave-length in feet of the wave radiated from the associated aërial, provided that the aërial radiating wire has been tuned to be in resonance with this oscillating circuit.

This instrument also provides the means of measuring small inductances, and also the frequencies in oscillating circuits, which are much higher than those which can be determined by photographing the spark.

2. *Eddy-current Losses in Three-phase Cable-sheaths.*[1] *By* M. B. Fields.

In three-phase electric power distributions the use of three-core lead-sheathed cables is common practice.

The alternating currents in the cable-cores induce eddy-currents in the sheath. If the cores have circular cross sections, and the current be evenly distributed over the section, the calculation of the sheath-loss (with certain reservations) is easy. Two effects exist which tend toward uneven current distribution in the cores: (1) the skin-effect, (2) the mutual induction effect of the cores on one another. Any uneven distribution of current flowing axially is shown to be equivalent to a uniform distribution superposed upon an eddy-current distribution (the eddy-currents flowing axially). The complete problem therefore includes the eddy-currents induced in the cores as well as in the sheath. The eddy-currents in the cores are considered under the headings of self-induced eddy-currents (skin-effect) and mutually induced eddy-currents. It is shown that owing to the manner in which cable-cores are made up in practice (being stranded and twisted) the calculation of the mutually induced eddy-currents is indeterminate, but if the stranding and twisting be sufficiently carefully executed these eddy-currents are negligible. The skin-effect in circular conductors does not materially complicate the calculation of sheath loss. The mathematical calculation is then given for three-core cables having cores of circular and segmental cross-sections. In this calculation the magnetic forces due to the sheath-currents may be, and are, neglected. It is shown that for different cables having similar cross-sections, working at the same current density in the cores, and at the same frequency, the sheath-loss per unit length varies as the sixth power of the diameter, and that were it desirable, from general considerations, to build large cables, this fact alone would limit the economical size. An example of a low-tension cable is then worked out.

The paper concludes by showing that just as the losses due to skin-effect of a given round conductor can be allowed for by assuming a definite increase of the specific resistance of the material for a given frequency, so in a three-core cable the extra loss due both to the skin-effect of the cores and the sheath-currents can be allowed for by assuming a definite increase of specific resistance of the core material for a given frequency. The formula for the increase of specific resistance is derived.

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3. *Magnetic and Electric Properties of Nickel at High Temperatures.* *By* Professor C. G. Knott.

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4. *On the Viscosity of Colloidal Iron Hydrate.* *By* A. D. Denning, *M.Sc., Ph.D.*

Simultaneous measurements of the viscosity of similar solutions were made (i) by finding the logarithmic decrement of a glass disc swinging in the solution according to the method described by Grotrian and W. König (readings obtained by mirror, lamp, and scale method), and (ii) by taking time of flow of a fixed volume through the capillary tube (Hagen-Poisseuille's transpiration method) of an Ostwald apparatus.

In order to more conveniently compare the results thus obtained by the two methods the logarithmic decrement was generally calculated by means of the O. E. Meyer formula from values of viscosity obtained by method (ii).

The initial values found for the viscosity η were, for method (i), $\eta_{20^\circ \text{C.}} = 0{\cdot}0146$; for method (ii), $\eta_{19{\cdot}6} = 0{\cdot}0144$; whilst for water $\eta_{17} = 0{\cdot}01105$.

[1] See also *Journal Inst. Elect. Eng*, vol. xxxiii. p. 936 (1904).

However, these values, especially for the swinging-disc method, were very considerably altered—

(i) By dialysing the liquid for three or four days: *e.g.*, not dialysed (*i.e.* by me), $\lambda = 0{\cdot}2018$; after first dialysis, $\lambda = 0{\cdot}2760$; after second dialysis, $= 0{\cdot}5162$.

(ii) After allowing disc to remain in solution for some time: *e.g.*, last-mentioned value had become $= 0{\cdot}9753$ after 2880 minutes.

(iii) By removing disc, washing it with water, and replacing it, caused large decreases in value: *e.g.*, as much as 63 per cent. was once observed.

(iv) By heating liquid to about 50° C. and allowing it to cool again, caused increase: *e.g.*, λ for the once-dialysed liquid became, after two such heatings, $= 0{\cdot}6571$; whilst for the twice-dialysed, after five such heatings, the author obtained a value as high as 1·8364, *i.e.*, nine times original value (0·2018).

These results gave some very good 'parallel' 'parabolic' curves.

(v) The influence of the size of the oscillation of disc was very marked with more viscous solutions: *e.g.*, $\lambda = 1{\cdot}3889$ for amplitude of 502 scale divisions; and $= 0{\cdot}6020$ for one of 42 divisions. These gave a good series of radial curves—*i.e.*, the more viscous the liquid the steeper the curves.

(vi) A violent shaking or accidental shaking, or making disc swing through large arcs, caused large decreases in values of λ.

Further, the 'zero-position' (with the more viscous solutions) of the image of the cross-wires on the scale suffered large displacements to right or left of initial position accordingly as the disc was set in motion by bringing up the N. or the S. pole of a magnet to the directing magnet supported above the disc: *e.g.*, on one occasion a displacement of as much as 658·5 scale divisions was obtained by holding second magnet for a few seconds near the directing magnet—this was with a small disc, when solution was very viscous.

An explanation of these apparently very irregular results is to be found in Professor Quincke's 'Schaum-zellen' theory of a colloid, viz., that such a 'pseudo-solution' really consists of two solutions, A and B (like milk or an emulsion of oil and water), the one, A, being rich in colloidal substance, heavier and more viscous than the other, B, and which possess at their common surfaces of separation a surface-tension, which will vary with the common surface, *i.e.*, with the formation of the small Quincke Schaumwände, particles, spheres, &c.

The values found by the transpiration method also showed a gradual increase during the course of these experiments, but far less strongly emphasised and not subjected to such irregularities. The flow of the colloidal solution through the solution in the one direction in the Ostwald apparatus does not favour the formation of the foam-cells, walls, &c.

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5. *Magnetic Double Refraction of Colloidal Iron Hydrate.* *By* A. D. DENNING, *M.Sc., Ph.D.*

The magnetic double refraction of iron salts has often been looked for, but up to the present only observed by J. Kerr ('Brush Grating Experiments,' *Brit. Assoc. Report*, 1901), and by Qu. Majorana (*Rendic. Acc. dei Lincei*, 1902) and Schmaus (*Ann. d. Physik*, 1903), with old specimens of 'Bravais's Iron.' These experimenters found very transient results and give no absolute values for the same.

Having found very remarkable results for the viscosity of the colloidal $Fe(OH)_3$ from Merck, it was deemed desirable to examine if solution would show properties of magnetic double refraction. But although the author made many (more than eighty) different experiments under various conditions—*i.e.*, after repeated dialysis, frequent heating and cooling, by varying concentrations and various magnetic field strengths in differently shaped polarisation tubes—he has only been able to find traces of such properties.

Only on one occasion have really measurable results with this solution from Merck been obtained. This was after slowly evaporating a portion until it contained approximately 20 per cent. Fe. Then, by placing a few drops between thin glass strips on the poles of the electro-magnet, a displacement of the interference

bands of a Babinet's compensator = $\frac{1}{40}$ wave-length with a field strength (= H) of 24,300 C.G.S. units was obtained. After $1\frac{1}{2}$ hours the displacement had decreased by 50 per cent.; on the next day no traces of the phenomenon were to be found.

Much more remunerative results were obtained with a solution of 'Bravais's Iron' obtained from a Heidelberg apothecary, *e.g.*, with a solution ($\sigma = 1{\cdot}0041$) containing 0·295 per cent. Fe ($= c$). A displacement ($= \beta$) of $\frac{3}{4}$ λ with a field strength (= H) of 4460 C.G.S. units was obtained in a polarisation-tube length ($= l$) = 5·5 centimetres—a value which gave a specific magnetic double refraction (k) = $0{\cdot}89 \times 10^{-8}$.

Further, the author was able to confirm Majorana's results that the phenomenon obeys the law

$$\beta = k\,\mathrm{H}^2 lc.$$

He found, further, that k decreased with the time: *e.g.*, the last value given above was 12 per cent. smaller after a lapse of ten days. He could not find that shape of trough or previous shaking of solution had an influence on the result.

Apparently the Merck ferric hydrate and the Bravais's iron have not the same chemical constitution.

Oddly enough, no solution of $Fe(OH)_3$ that was in the Heidelberg Physics Institute during the course of above experiments showed traces of double refraction, when subjected to a sudden and quick motion, as previously found by Professor Quincke (*Ann. d. Physik*, 1902).

Schmaus's explanation of the suspension character of the solution is nothing more than Quincke's 'Schaum-Theorie.'

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6. *An Experimental Verification of Newton's Second Law.* *By* W. D. Eggar, *M.A.*

Teachers of dynamics have recourse to the movements of the heavenly bodies for supplying the proof of Newton's Laws; and Galileo's work is as a rule neglected. As the average student of dynamics is not an astronomer, modern scientific methods seem to require something more tangible, and this paper describes an attempt to supply it. The acceleration is measured by the wave-lengths traced on a moving trolley by a vibrating steel spring carrying a paint-brush. The trolley runs down a plane of which the inclination can be varied, and the force down the plane is measured by the weight which, hanging over a pulley, will just permit the trolley to run down with uniform speed. The apparatus of the trolley and steel spring is described by Mr. W. C. Fletcher (Chief Inspector of Secondary Schools) in the 'School World' for May 1904. Mr. Fletcher used the same force with varying masses. The writer of the paper has adapted the method to the same mass moving under varying forces.

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7. *On a Modification of FitzGerald's Model of the Ether.* *By* J. Butler Burke.

FitzGerald represented the mechanism of the electro-magnetic field by a number of parallel wheels connected with india-rubber bands passing round their circumferences, the wheels rotating round parallel axes.

Thus, if one of the wheels rotates faster than the rest the bands round it become strained on one side and loosened on the other. This represents the state of polarisation, the opposite sides being in opposite states.

If the axes are connected by strong springs instead of being fixed to a board, we have a model of an ether which transmits the ordinary electro-magnetic displacements, and at the same time behaves as an elastic solid, thereby transmitting longitudinal and another class of distortional waves. Such an ether, which would be slightly compressible, would, although approximately satisfying Maxwell's equations, at the same time propagate longitudinal waves. These waves, if they exist

throughout all space, would give rise to gravitational force between bodies varying inversely as the square of the distance, and, if of sufficiently high frequency, much higher than the Röntgen rays, the absorption would be proportional to the mass, and so also would be the pressure.

The velocity of propagation would be very much greater than that of light, and this would therefore not be open to Laplace's objection that gravitation, if it were propagated at the same speed as light, would give rise to planetary disturbances which could easily be detected.

The frequency would have to be very great, so that the law of force should be that of the inverse square for small bodies. It seems therefore in accordance with this theory that the wave-length is comparable with the molecular dimensions when the law of attraction no longer follows the inverse square law. It is noteworthy that the hydrogen molecules repel when those of other gases attract. Thus the longitudinal wave-length would appear to be comparable with the dimension of the hydrogen molecule. The repulsion is due to the pressure of the scattered radiation. Similarly with electrons. But although two hydrogen atoms or any two molecules of that order of magnitude may repel each other, and also two electrons, yet a large molecule will attract a very much smaller one, so that a molecule the dimensions of hydrogen atoms will attract an electron because of the screening action of the larger molecules on the smaller. This appears to be in accordance with electrostatic attraction of unlike charges and repulsion of like ones. Thus the theory is promising in many ways, and is being developed further.

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8. *On the Electric and Thermic Conductivities of certain Alloys of Iron. By* Professor W. F. Barrett, *F.R.S.*, and R. A. Hadfield.

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9. *On a New Apparatus for producing Magnetic Fields of Force. By* Professor Marcus Hartog.

From a square base-plate of cast iron arise four brass columns with a screw-thread on their upper ends to take large flat nuts, which support a wooden plate with circular perforations at regular intervals. On the iron plate rest the electromagnets (*b*), each consisting of a cylindrical coil (*c*) with both terminals below, and a cylindrical soft iron core which projects through a hole in the wooden plate. A source of direct current, an amperemeter, a rheostat, and a mercury commutator (*e*) (to allow of the ready alteration of the direction of the current in the individual coils), complete the apparatus. The material I employ is magnetite (mineral Fe_3O_4), finely powdered and levigated, or iron filings levigated in alcohol; this powder may be shaken on paper or suspended in glycerine, balsam dissolved or melted, or liquefied gelatine. As a rule a thin layer of the mixture is sufficient, spread on a glass or china plate giving an axial section of the field. I have with this apparatus produced several interesting variants of the classical figures of the magnetic field obtained by the agitation of paper strewn with iron filings.

Sub-Section of Astronomy and Cosmical Physics.

The following Reports and Papers were read:—

1. *Report on the Magnetic Observations at Falmouth Observatory.* See Reports, p. 29.

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2. *Report on Meteorological Observations on Ben Nevis.*—See Reports, p. 55.

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3. *Some Results with the Solar Physics Observatory Photo-Spectro-Heliograph.* *By* WILLIAM J. S. LOCKYER, *M.A., Ph.D., F.R.A.S.*

This paper contained a description of the spectro-heliograph and the results which have been produced with it.

The complete instrument for taking photographs of the sun in monochromatic light consists of three parts: a siderostat, a lens for throwing the solar image on the primary slit, and the spectro-heliograph.

The first carries a plane mirror of 18 inches in diameter and has electric slow motions which are operated at the spectro-heliograph. The lens, a Taylor photo-visual, has an aperture of 12 inches and a focal length of 18 feet. The spectro-heliograph moves horizontally in a direction at right angles to the incident beam on the primary slit. It consists of one triangular frame moving on another triangular frame, the former rolling on three balls supported by the latter. This movement is operated by a falling weight, and controlled by a piston moving in an oil chamber. On the movable frame is fixed a double tube, at the extremities of which are fixed the two 4-inch Taylor photo-visual lenses and the two slits. The spectrum is formed in the plane of the secondary slit by means of a 6-inch plane mirror and a 6-inch prism of 45° angle. Nearly in contact with the secondary slit, but independent of its motion, is placed the plate-carrier. The diameter of the solar image on the primary slit is $2\frac{1}{6}$ inches, and this is also the size of the monochromatic image at the secondary slit. The dispersion is such that the length of spectrum from F—K is 1·62 inches.

The secondary slit is so adjustable that the 'K' line of calcium can be completely isolated, and this slit is also so curved that the line can be isolated throughout its whole length.

Up to the present time the 'K' line has alone been utilised, and, whenever possible, photographs have been secured of the 'K' radiations on the disc and those round it. In the case of the former, with a summer sun and untarnished mirrors, good pictures can be secured in 15 *seconds*, but this time has to be considerably prolonged during the other months of the year.

In the case of the 'K' radiations round the disc, or the prominences, under similar weather conditions, 15 *minutes* is required for a full exposure. These pictures are obtained by placing in front of the primary slit a metal disc equal in diameter to the solar image.

The photographs exhibited showed numerous pictures of the disc taken during May, June, and July of the present year, all of which showed fine detail and surface mottling. Several composite photographs, that is, pictures showing the solar disc and limb photographed on the same plate but consecutively, were also exhibited.

Attention was also drawn to the very rapid changes which the prominences on the limb underwent in comparatively short intervals of time. Thus, on July 14 a prominence in the north-west quadrant of the sun in an interval of one hour changed from 160,000 miles in length to 96,000 miles, while its height increased from 50,000 to 60,000 miles in the same time.

Another instance occurred on July 19, when an enormous prominence, 192,000 miles in length, grew to 216,000 miles in five hours. At the same time its height changed from 55,000 to 60,000 miles.

At the present time the instrument is being employed to obtain, as far as is possible, a daily record of the 'K' radiation on the disc and the prominences on the limb; but it is hoped, as soon as a sufficiently large grating can be secured, to investigate the distribution of other substances.

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4. *On the Unsymmetrical Distribution of Rainfall about the Path of a Barometric Depression.* *By* HUGH ROBERT MILL, *D.Sc.*

Heavy rains are usually divisible into those accompanying thunderstorms and those accompanying ordinary cyclonic disturbances. In ten cases of the latter

type occurring in the British Isles, maps were prepared on which the areas receiving a rainfall exceeding half an inch, one inch, two inches, &c., were laid down from the daily observations of observers reporting to 'British Rainfall.' The path of the associated cyclone was inserted from the Monthly Summary o' the 'Weekly Weather Report.'

In nine of these cases it was found that, irrespective of the direction in which the cyclone travelled, the area of heavy rainfall (exceeding one inch in twenty-four hours) lay almost entirely on the left of the path, and that the wet area was in advance of the centre. The tenth case was one of nearly symmetrical distribution about the path.

The relationship cannot be accidental, and suggests both theoretical and practical considerations of great interest, according with the views of the circulation of air in a cyclone recently put forward by Dr. W. N. Shaw, and suggesting a more definite basis for forecasting heavy rains.

It must of course be remembered that all cyclones of equal depth of depression and rate of progressive movement are not rain-bearing to the same extent. The cyclone of February 27, 1903, which produced most disastrous damage by wind, brought little rain. The somewhat similar depression of September 10, 1903, remembered as occurring during the meeting of the British Association at Southport, brought a widespread rainfall, but no very serious wind.

The remarkable rainfall of June 13, 14, and 15, 1903, between Cambridge and the Thames Valley, when one inch or more per day fell on three consecutive days, was associated with a depression which followed an elliptical path with the wettest area always on its left, a very unusual course, producing an unprecedented rainfall in a comparatively dry area.

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5. *The Application to Meteorology of the Theory of Correlation.* *By* Miss F. E. Cave.

During the last few years the methods of the theory of correlation have been applied to the records of barometric observations taken during the years 1879 to 1898 at various stations on each side of the Atlantic. The correlations between Wilmington (North Carolina) and Halifax (Nova Scotia), two stations about a thousand miles apart, have been calculated, different intervals being allowed between the corresponding observations. The magnitude of the correlation varies with the interval, being greatest when Halifax is taken one day later than Wilmington. This seems to indicate a drift of barometric conditions northwards and eastwards; and the satisfactory results obtained in this case encourage the writer to hope that the application of similar methods to readings taken at stations on opposite sides of the Atlantic, a longer interval being allowed, may lead to the discovery of correlations sufficiently large to be of use in the practical work of prediction.

It has also been found that the correlation between simultaneous barometric heights at two stations lying north and south of each other, at a sufficient distance apart, may be a negative quantity of considerable magnitude, and that the correlation varies with the distance in a manner which deserves further investigation.

The application to meteorology of the theory of correlation may be of importance, both for prediction and also in leading up to fuller knowledge of the laws of the atmosphere, by supplying more detailed information than is otherwise obtainable as to the connection between different stations as regards either the barometric heights there or any other of the quantities with which meteorology deals.

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6. *The Development of the Aeroplane.* *By* Major B. Baden-Powell.

The day is undoubtedly drawing near when we shall be utilising the highway of the air for travel, and it is now becoming an interesting question as to what form the motor car of the skies is to take.

During the last few years much has been done in the construction of navigable balloons, but only proving, in my opinion, how insuperable are the difficulties of attaining really practical results. The aeroplane, which may be defined as a plane surface propelled through the air at a small horizontal inclination, so that the resulting pressure of the air supports it against the action of gravity, gives promise of far better results. Wings, vertical-acting screws, and aeroplanes proper all come under this definition. The action of the air on an inclined surface requires more study, as theory and practice in this matter are at considerable variance.

With small models, as shown, a vertically lifting screw can, despite theory, lift as great a weight into the air as a horizontally propelled plane. I have been making a number of experiments in this line, as well as with man-carrying aeroplanes driven by the impetus gained by sliding down an inclined plane. The latter have been chiefly to get at an idea of the strength required in the different parts of construction, and to test the balance of the machine. But results in all these lines tend to show that a great amount of careful experiment is necessary before we can hope for good results, though the prospects are decidedly hopeful.

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7. *Plato's Theory of the Planets.* *By* Professor D'Arcy W. Thompson, *C.B.*

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8. *Report on Underground Temperature.*—See Reports, p. 51.

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9. *Zur Flugfrage.* *By* Dr. F. Hirtel.

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10. *Upper Air-currents and their Relation to the Audibility of Sound.* *By* Rev. J. M. Bacon.

Investigations carried out during a long series of balloon ascents have revealed a very remarkable complexity in the upper air-currents which, from their nature, would escape the notice of the observer on earth. A number of light bodies, of varying sizes and differently constituted, have been prepared and allowed to float away into space at different heights and under different circumstances; and these, carefully watched, have shown the existence of minor but headlong currents, holding determined courses frequently at variance with that of the balloon. It has been proved that dominant but diverse air-streams will glide one above another in juxtaposition without commingling, and that upper currents maintaining the same level will occasionally alter their course, presumably in obedience to some configuration of the earth below; while, at all heights, ascending or descending air-streams, greater or lesser, will obtrude themselves in a way which is often wholly unaccountable.

In a manner equally capricious, and apparently dependent on the above, sounds conveyed through the upper air will be carried sometimes to abnormal distances in directions at variance with the ground current, being borne to earth over far but favoured plots of ground, while they may pass unheard over districts which might be considered well within sound range. These results, which have been obtained largely by organised observation of the hearing of aerial bombs, will presumably account for the occasional surprisingly far travel of sound signals; or, again, their failure at short ranges.

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11. *On the Effect of Electric Air-currents.* *By* Professor Selim Lemström.

The author, after referring to suggested explanations of the magnetic and electrical conditions of the earth, draws attention to the fact established by Wijkander that

the sign of the variations of magnetic declination changes on passing from one side to the other of the 'belt of polar light,' that is, of the belt of maximum frequency of displays of the *aurora borealis.* He regards this fact as proving that the aurora is caused by vertical (or nearly vertical) electric discharges in the atmosphere above the belt of auroras. In connection with this he mentions that during the Finnish International Polar Expedition to Sodankylã and Kultala, real auroral beams, showing in the spectroscope the characteristic auroral line $\lambda = 5569$, were produced on mountain-tops in Finnish Lapland 'by means of a simple point apparatus conducted to the earth.' On not fewer than sixteen occasions the same ray was observed in all directions when there was no visible aurora, and it was found that the air itself radiated the light producing this ray.

The author goes on to state that during several expeditions to the Polar regions he had observed the rich development of vegetation during the short summer, an observation which had also been made by others. In consequence of experiments made subsequently, he was led to attribute this luxuriance of vegetation to the electric air-currents prevalent in the auroral belt. The experiments referred to were performed by means of a network of wire furnished with points and supported on insulating poles above the ground. This was connected with the positive pole of a modified form of Wimshurst electrical machine, the negative pole of which was connected with the earth. The author finds that the electric air-currents brought about in this way will produce, if duly applied, such effects as the following:—

1. An increased growth of all plants, amounting in an ordinary good field to about 40 per cent.

2. A change in the chemical composition of grain and roots resulting in an augmentation of the protein and albumenoid matter in rye of about 20 per cent., in barley of about 12 per cent., and of about 9 per cent. in oats, and causing an increase in the amount of sugar in sugar-beets of from 13 to 18 per cent.

The author has no doubt that similar changes would take place in all sorts of plants under the like conditions, and he commends the matter (further details of which he has given in a small book entitled 'Electricity in Agriculture and Horticulture,' published by the 'Electrician' Publishing Company, London, 1904) to the attention of those who may have the opportunity of experimenting further upon it.

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12. *The Rainfall of the Midland and Eastern Counties of England.* *By* JOHN HOPKINSON, *Vice-Pres. R.Met.Soc., Assoc.Inst.C.E.*

This paper concludes the series on the rainfall of the English counties, and contains an account of the rainfall of Shropshire, Stafford, Warwick, Leicester and Rutland, Northampton, Huntingdon, Bedford, Cambridge, Norfolk, and Suffolk. These counties comprise an area of 10,626 square miles, which is rather more than one-fifth that of England, and between one-eleventh and one-twelfth that of the British Isles. The mean monthly rainfall for the ten years 1881 to 1890 at 52 stations in these counties has been computed, and the mean annual rainfall at 106 stations, being one to the nearest 100 square miles in each county. Rutland is included with Leicester on account of its small area, 149 square miles; and of the ten stations allotted to the two counties, Leicester, with 806 square miles, has eight, and Rutland two. Norfolk is much the largest of these counties, having an area of 2,026 square miles, its annual rainfall, therefore, being computed from the records of 20 stations.

The annual means at the 106 stations are:—Shropshire (13 stations), 30·36 inches; Stafford (12 stations), 28·98 inches; Warwick (8 stations), 26·64, inches; Leicester and Rutland (10 stations), 26·62 inches; Northampton (10 stations, 25·81 inches; Huntingdon (4 stations), 23·39 inches; Bedford (5 stations), 22·59 inches; Cambridge (8 stations), 22·90 inches; Norfolk (20 stations), 25·44 inches; and Suffolk (15 stations), 24·76 inches; the mean rainfall for the whole area being 26·29 inches.

During the ten years 1881 to 1890 the rainfall in this part of England was

rather less than that for the twenty-five years ending 1890 and that for the thirty years ending 1895. Twenty stations give a mean for the ten years 1881–90 of 25·99 inches, for the twenty-five years 1866–90 of 26·96 inches, and for the thirty years 1866–95 of 26·58 inches, the excess in this latter period thus being 0·59 inch, or about 2¼ per cent., over the mean fall at the same stations for the ten years 1881–90. The true mean for the 106 stations for the thirty years would, therefore, probably be a little under 27 inches.

The mean fall for the thirty years at the 20 stations in five-yearly periods was as follows:—For the first lustrum, 1866–70, 25·25 inches; for the second, 1871–75, 27·45 inches; for the third, 1876–80, 30·11 inches; for the fourth, 1881–85, 27·79 inches; for the fifth, 1886–90, 24·19 inches; and for the sixth, 1891–95, 24·68 inches.

The monthly and annual means for each county and for the whole area at the 52 stations are as follows:—

Mean Rainfall in the Midland Counties of England, 1881–90.

—	Shropshire, 5 Stations	Staffordshire, 8 Stations	Warwickshire, 5 Stations	Leicester & Rutland, 7 Stations	Northamptonshire, 4 Stations	Huntingdonshire, 1 Station	Bedfordshire, 2 Stations	Cambridgeshire, 4 Stations	Norfolk, 11 Stations	Suffolk, 5 Stations	Mean, 52 Stations
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
January .	2·68	2·15	2·03	1·89	1·94	1·31	1·47	1·41	1·72	1·58	1·89
February .	2·07	1·76	1·80	1·78	1·88	1·26	1·37	1·33	1·57	1·47	1·68
March .	2·09	2·06	1·77	1·85	1·73	1·29	1·47	1·43	1·72	1·61	1·78
April .	2·04	1·88	1·87	2·00	1·76	1·84	1·71	1·52	1·55	1·49	1·76
May .	2·63	2·32	2·27	2·28	2·10	2·07	1·97	1·91	1·76	1·71	2·10
June .	2·42	2·50	2·22	2·00	1·84	1·77	1·94	1·94	1·79	1·62	2·03
July .	2·68	2·65	2·77	2·61	3·02	3·12	2·50	2·63	2·72	2·60	2·70
August .	2·84	2·73	2·37	2·56	1·94	2·13	1·93	2·02	2·19	1·95	2·34
September .	2·45	2·59	2·34	2·29	2·28	2 52	2·06	2·27	2·66	2·64	2·46
October .	3·21	2·90	2·73	2·93	2·61	2·52	2·30	2·58	3·26	3·14	2·94
November .	3·46	2·93	2·90	2·57	2·66	2·21	2·22	2·23	2·62	2·56	2·71
December .	2·47	2·34	2·00	2·07	1·90	1·54	1·64	1·71	2·11	1·99	2·08
Year .	31·04	28·81	27·07	26·83	25·66	23·58	22·58	22·98	25·67	24·36	26·47

The rainfall in these counties follows the general rule of increase from east to west, except near the sea-coast on the east. Dividing the counties into three groups—west, midland, and east—34 stations for the western group, Shropshire, Stafford, and Warwick, give an annual mean of 28·88 inches; 37 stations for the middle group, Leicester, Rutland, Northampton, Huntingdon, Bedford, and Cambridge, give an annual mean of 24·73 inches; and 35 stations for the eastern group, Norfolk and Suffolk, give an annual mean of 25·15 inches. In the first group the driest months are: February, mean 1·88 inch; March, mean 1·97 inch; and April, mean 1·93 inch. In the second group the driest months are: January, mean 1·60 inch; February, mean 1·52 inch; and March, mean 1·55 inch; and in the third group the driest months are February and April, each with a mean fall of 1·52 inch, while January and March are nearly as dry, the former having a mean fall of 1·65 inch and the latter of 1·66 inch. In the first group the wettest months are October, mean 2·95 inches, and November, mean 3·10 inches; in the second group the wettest months are July, mean 2·78 inches, and October, mean 2·59 inches; and in the third group the wettest month is October, mean 3·20 inches, July following with 2·66 inches, September with 2·65 inches, and November with 2·59 inches.

Huntingdon, Bedford, and Cambridge are the driest counties, except in April, when Suffolk is the driest, Norfolk drier than Huntingdon and Bedford, and

Northampton drier than Huntingdon; in May, when Norfolk and Suffolk are the driest; in June, when Suffolk is the driest and Norfolk and Northampton are drier than Bedford and Cambridge; in July, when several counties are drier than Huntingdon, and Suffolk and Leicester drier than Cambridge; in August, when Northampton and Suffolk are drier than Huntingdon and Cambridge; and in September, when Northampton is drier than Huntingdon.

Shropshire is the wettest county, except in June, when Stafford is the wettest, and in July and September, when several counties are wetter.

Particulars of the stations, with the mean and extreme annual rainfall at each, are given with the complete paper, and also a map showing the position of the stations and their height above mean sea-level.

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13. *The Rainfall of England*, 1861–1900.
By John Hopkinson, *Vice-Pres. R.Met.Soc., Assoc.Inst.C.E.*

The rainfall of the English counties has been dealt with in a series of papers read before the Association, each treating of a group of counties: the South-Western at the Bristol meeting in 1898, the South-Eastern at the Dover meeting in 1899, the Northern at the Bradford meeting in 1900, and the Midland at the present meeting. It now remains to summarise the general results and to extend the period, so far as annual rainfall is concerned, to the end of the nineteenth century.

The following table gives the monthly rainfall of each group of counties and of the whole of England for the ten years 1881–1890:—

Table I.—*Mean Monthly Rainfall in England*, 1881–90. (288 *Stations.*)

Counties	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Northern . . .	3·04	2·32	2·82	2·15	2·50	2·27	3·60	3·19	3·14	3·72	3·72	3·09
Midland . .	1·89	1·68	1·78	1·76	2·10	2·03	2·70	3·34	2·46	2·94	2·71	2·08
South-Eastern .	2·14	1·91	1·84	1·77	1·97	1·86	2·50	2·07	2·37	2·97	3·06	2·24
South-Western .	3·06	2·63	2·49	2·30	2·31	2·33	3·12	2·66	2·88	3·59	4·10	3·32
England .	2·62	2·18	2·31	2·03	2·25	2·14	3·05	2·63	2·77	3·37	3·47	2·76

It will be seen that the Northern and South-Western counties have much more rain throughout the year than the Midland and South-Eastern. In each month from January to July the Northern and South-Western counties alternate in being the wettest; from July to October the Northern are the wettest; and in November and December the South-Western. From January to April the Midland counties are the driest; from May to September the South-Eastern are the driest; and from October to December the Midland. In spring and summer the Northern counties are wetter than the South-Western; in autumn and winter there is very little difference between them. In summer the South-Eastern counties are drier than the Midland; in winter the Midland are drier than the South-Eastern; in spring and autumn they are about the same.

These results are from the records of 288 stations, and the annual means are: Northern counties (94 stations), 35·56 inches; Midland (52), 26·47 inches; South-Eastern (70), 26·72 inches; South-Western (72), 34·79 inches. The annual means computed for 502 stations, one station to every 100 square miles in each county, for the same period, are: Northern counties (184 stations), 36·16 inches; Midland (106), 26·29 inches; South-Eastern (99), 26·80 inches; South-Western (113), 34·08 inches. The mean fall for the whole of England, computed for the 288 stations, is 31·59 inches, and for the 502 stations 31·76 inches. These results are sufficiently

close to show that the stations from which the monthly means are deduced are fairly representative.

Although 502 stations may be a sufficient number from which to compute the rainfall of England for a given period, a much longer period than ten years is required for an estimate of the true average to be arrived at. For this the shortest period which can be taken is thirty years, and forty years give a more satisfactory result. But when we come to work at this period the difficulty arises that the number of consecutive records is inadequate. This difficulty may to some extent be overcome by computing the probable rainfall for the larger number of stations from that at the smaller number for a long period.

The following table gives the rainfall in 5-yearly periods from 1861 to 1900 at 50 stations, 18 being in the Northern counties, 11 in the Midland, 10 in the South-Eastern, and 11 in the South-Western:—

TABLE II.—*Mean Annual Rainfall in England,* 1861–1900. (50 *Stations.*)

Counties	1861-65	1866-70	1871-75	1876-80	1881-85	1886-90	1891-95	1896-1900	1861-1900
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Northern . .	34·43	37·13	37·75	38·92	38·22	33·34	34·98	35·68	36·31
Midland . .	22·40	24·07	26·90	29·35	27·04	23·79	23·82	22·62	24·99
South-Eastern .	25·85	27·80	28·39	31·62	27·60	25·80	27·45	27·72	25·03
South-Western .	31·23	33·65	37·57	38·75	35·46	30·55	31·86	31·55	33·83
England . .	29·36	31·63	33·45	35·51	33·03	29·14	30·32	29·91	31·54

The mean rainfall at the 50 stations for the ten years 1881-90 being 31·08 inches, and for the forty years 1861–1900, 31·54 inches, and the mean rainfall at the 502 stations for the ten years 1881–90 being 31·76 inches, it follows by proportion that the mean for the forty years for the 502 stations would be 32·23 inches, or thereabouts.

Other periods may also be taken, and the following table gives the results of comparison with the ten years 1881–90 of the mean rainfall at 16 stations for sixty years, at 50 for forty years, and at 100 for twenty-five years:—

TABLE III.—*Mean Annual Rainfall in England for Various Periods compared with* 1881–90.

Counties	16 Stations			50 Stations			100 Stations			502 Stations	
	No.	1841–1900	1881–90	No.	1861–1900	1881–90	No.	1866–90	1881–90	No.	1881–90
		Ins.	Ins.		Ins.	Ins.		Ins.	Ins.		Ins.
Northern . .	6	36·45	36·68	18	36·31	35·78	40	39·80	38·54	184	36·16
Midland . .	3	25·51	25·96	11	24·99	25·91	20	26·96	25·99	106	26·29
South-Eastern .	3	29·08	28 20	10	25·03	26·70	20	27·79	26·19	99	26·80
South-Western .	4	37·53	36·08	11	33·83	33·00	20	37·66	35·86	113	34·08
England . .	16	33·21	32·93	50	31·54	31·08	100	34·40	33·02	502	31·76

By proportion the probable mean rainfall for the twenty-five years 1866–90 (a wet period) comes out as 33·09 inches, and for the sixty years 1841–1900 as 32·03 inches. It must be understood that the results for the 16, 50, and 100 stations are considered of value only for comparing one period with another, and not as giving in themselves a true indication of the actual mean rainfall of the periods to which they relate.

By the same method of computation, carried out in a somewhat different manner, gradually extending the period, with a smaller and smaller number or stations, a slightly different result was arrived at, the mean rainfall of England coming out at 32·41 inches for the forty years 1861–1900, for the sixty years 1841–1900 at 32·28 inches, and for the seventy years 1831–1900 at 32·25 inches. Taking into consideration the extreme variability of rainfall, the divergence in these results is too small to affect the value, for all practical purposes, of this method of computing average rainfall, and it is extremely improbable that any method of equal or greater accuracy by which the average rainfall over England may be computed for a long period will give a result appreciably less than 32 or more than $32\frac{1}{2}$ inches.

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION—Professor SYDNEY YOUNG, D.Sc., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

THE researches of Hermann Kopp on the molecular volumes and boiling-points of chemical compounds extended over half a century, beginning with his inaugural dissertation on the densities of oxides in 1838, and concluding in 1889 with a review of the whole of the work done on the subject. In his second paper Kopp considered the molecular volumes of solid compounds, and arrived at the conclusion that truly isomorphous substances have the same atomic or molecular volume, but that in other cases the volumes are usually different. Schröder also made the same observation at about the same time.

Now, isomorphous substances have analogous chemical formulæ, and are usually of similar chemical character, and it is interesting to notice that at this early date the fact was recognised that close chemical relationship is associated with similarity in physical properties.

For about the first six years Kopp was engaged in the consideration of the results obtained by other observers, and from these results he deduced the most important of his generalisations.

As regards boiling-points, Kopp, in 1842, concluded that a constant difference in chemical composition is accompanied by a constant difference in boiling-point, and he adopted the value 18° as the rise due to the replacement of the methyl by the ethyl group in organic compounds, although the observed differences varied between 11°·0 and 24°·8. Two years later he found in sixteen comparisons differences varying from 8° to 33°; but he doubted the correctness of the extreme values, and took 19° as the true value; he further suggested that this is the constant difference for an addition of CH_2 in any homologous series, and he pointed out that the observed difference was most regular in the case of the fatty acids.

Kopp was also of opinion that isomeric compounds with the same composition and the same vapour density have the same boiling-point.

The paucity of experimental data and the wide discrepancies between the results obtained by different observers induced Kopp to undertake the determination of the boiling-points of various compounds, and, later, their molecular volumes at a series of temperatures, and it is interesting to note the comparative crudeness of his first attempts and the increasing attention which he paid to the purification of his compounds and to the elimination of thermometric and other errors. He first examined three pairs of esters in order to find whether isomeric compounds have really the same boiling-points. But he employed only calcium chloride as a dehydrating agent, and this would remove neither water nor the alcohol completely; he was much troubled by the 'bumping' of the liquids, and the temperatures he actually observed—with the thermometer bulb in the liquid—fluctuated considerably, and he could only, in most cases, take the lowest temperature observed as the most probable boiling-point. By so doing, and by making a fairly liberal allowance for residual errors, Kopp arrived at the erroneous conclusion

that the boiling-points of isomers were the same in the three cases examined, and therefore, probably, in all cases.

The boiling-point of methyl alcohol was of great interest to Kopp, because, taking that of ethyl alcohol—about which there was general agreement—as correct, it should, according to his law, be $78° - 19° = 59°$, while the temperatures actually observed varied from 60° to 66°. Kopp prepared a specimen of methyl alcohol, and found that it boiled at about 65°; but he had more faith in his law than in his experimental result, and he concluded that the methods of determining boiling-points were not sufficiently accurate to give results correct to within even 1° or 2°.

In 1854 he discussed the corrections which should be applied to thermometer readings, giving a table of corrections for the unheated column of mercury, and adopting the value 27 mm. per degree as the value of $\frac{dp}{dt}$ for all substances, in order to reduce the observed boiling-point to that at normal pressure. He pointed out, also, that the height of the barometer should be reduced to 0° C. Taking advantage of Delff's improved method of preparing and purifying methyl alcohol, Kopp made a fresh specimen from methyl oxalate and dried it with lime; but while Delff observed the boiling-point to be 60°, Kopp obtained the value $65°{\cdot}2 - 65°{\cdot}8$. He was still, however, inclined to think that, owing to bumping, the observed boiling-point was too high and that the true temperature should be about 60°.

Meanwhile, in 1847 Kopp had examined sixteen liquids, including water, two alcohols, three fatty acids, and seven esters, and in 1854, as a result of his further determinations, he was able to compare the boiling-points—and also the molecular volumes—of a large number of substances, most of which were either alcohols, acids, or esters, and he at first adhered to his previous value of 19° for the rise of boiling-point due to the addition of CH_2. Later in the same year, however, taking a wider survey and including hydrocarbons and their halogen derivatives, ethers, sulphides, and other compounds, he was obliged to admit that the difference is in some cases higher, in others lower, than 19°, but he still regarded these cases merely as exceptions to the law. In 1867 Kopp admitted that isomeric aromatic hydrocarbons have not always the same boiling-point, and that the difference for an addition of CH_2 was not always 19°; but he still believed that the difference for CH_2 was constant in any really homologous series—for example, 20°·5 for homologues of toluene, 18°·5 for those of xylene, and 16°·5 for those of trimethylbenzene. He also recognised the fact that isomeric alcohols have widely different boiling-points.

Kopp published no later papers on the boiling-points of organic compounds, although he dealt fully with the question of molecular volumes in his final communication in 1889.

As a pioneer, Kopp had very great difficulties to contend against when he began his researches; data were scanty and far from accurate, and the substances which could be most easily obtained and, it was thought, readily purified were, unfortunately, those which were the least likely to lead to normal generalisations. Water, the alcohols, and the organic acids all contain a hydroxyl group, and we now know that the physical properties of these substances are abnormal in nearly all respects, owing, probably to the fact that their molecules tend to associate together; moreover, the esters, which are formed by the interaction of acids and alcohols, do not behave quite normally, and there is probably molecular association, though to a much smaller extent than with the hydroxyl compounds.

There can be little doubt that if Kopp had been able, in the first place, to obtain a considerable number of pure substances of normal behaviour, such as the paraffins or their halogen derivatives, he would not have been led to the erroneous conclusions which he defended with such vigour for so many years. If we take the normal paraffins as the simplest class of organic compounds, we find that, instead of the boiling-points rising by equal intervals as the series is ascended, the rise, which is very large for the lowest numbers, becomes smaller and smaller as the molecular weight increases. This fact is, of course, now well

known, and various formulæ have been suggested to reproduce these boiling-points. Thus Walker has proposed the formula $T = aM^b$, where T is the boiling-point on the absolute scale of temperature, M is the molecular weight, and a and b are constants. Ramage has this year suggested that this formula applies only to the CH_2 chain linkage, and that the influence of the terminal hydrogen atoms is considerable in the case of the lowest members, but diminishes as the chain lengthens, and becomes eventually either constant or negligible. In other words, the lower members of the series cannot be regarded as truly homologous, and that is a point which is, I think, important to bear in mind. Ramage suggests a new formula, $T = a[M(1-2^{-n})]^{\frac{1}{3}}$, where a is Walker's constant, 37·3775, and n is the number of carbon atoms in the molecule. He assumes, however, a constant difference for CH_2 in the case of the alcohols, the aldehydes, and the ketones, but I doubt whether the boiling-points of the last two classes of compounds are yet sufficiently well established to allow of any certain conclusions being drawn from them.

I am inclined to think that it may be useful to regard the value of Δ (the rise of B.P. for an increment of CH_2) as being mainly a function of the absolute temperature, and I would provisionally suggest the formula $\Delta = \frac{144 \cdot 86}{T^{0 \cdot 0148\sqrt{T}}}$, where Δ is the difference between the boiling-point, T, of any paraffin and that of its next higher homologue. Taking the boiling-point of methane as 106°·75 abs., the values for the higher members agree better with the observed temperatures than those given by Ramage's formula, as will be seen by the table below :—

Paraffin	Boiling-point (abs. temp.)				
	Observed	Calculated. Ramage	Δ	Calculated. Young	Δ
CH_4	108·3	105·7	−2·6	106·75	−1·55
C_2H_6	180·0	177·3	−2·7	177·7	−2·3
C_3H_8	228·0	231·9	+3·9	229·85	+1·85
C_4H_{10}	274·0	275·6	+1·6	272·6	−1·4
C_5H_{12}	309·3	312·2	+2·9	309·4	+0·1
C_6H_{14}	341·95	343·9	+1·95	341·95	0
C_7H_{16}	371·4	372·3	+0·9	371·3	−0·1
C_8H_{18}	398·6	398·3	−0·3	398·1	−0·5
C_9H_{20}	422·5	422·5	0	422·85	+0·35
$C_{10}H_{22}$	446·0	445·2	−0·8	445·85	−0·15
$C_{11}H_{24}$	467·0	466·8	−0·2	467·35	+0·35
$C_{12}H_{26}$	487·5	487·3	−0·2	487·65	+0·15
$C_{13}H_{28}$	507·0	507·0	0	506·8	−0·2
$C_{14}H_{30}$	525·5	526·0	+0·5	525·0	−0·5
$C_{15}H_{32}$	543·5	544·2	+0·7	542·3	−1·2
$C_{16}H_{34}$	560·5	561·9	+1·4	558·85	−1·65
$C_{17}H_{36}$	576·0	579·0	+3·0	574·7	−1·3
$C_{18}H_{38}$	590·0	595·7	+5·7	589·9	−0·1
$C_{19}H_{40}$	603·0	611·9	+8·9	604·5	+1·5

I do not wish, however, to lay much stress on the actual form of the equation, or on the particular values of the constants; the chief point I wish to call attention to is that Δ may be regarded as a function of the temperature.

Suppose that we replace a terminal atom of hydrogen in each normal paraffin by chlorine, so as to form the homologous series of primary alkyl chlorides. The boiling-points of these chlorides are much higher, and the differences, Δ, are much smaller than for the corresponding paraffins, but the gradual fall in the values of Δ as the series is ascended is unmistakable. The same remarks apply to the bromides and iodides, the boiling-points being still higher and the values of Δ smaller.

But the point of chief interest appears to me to be this: if the values of Δ for

the halogen derivatives are plotted against the absolute temperatures, the points for the most part fall near the curve constructed for the paraffins, and represented by the formula $\Delta = \dfrac{144 \cdot 86}{T^{0 \cdot 0148 \sqrt{T}}}$. The first value of Δ is decidedly low in each case (average deviation from curve 2°·7); the later ones are rather high in nearly every case (average deviation 0°·86). Similar results are in general obtained with other homologous series of compounds in which molecular association is not believed to occur, but, as will be seen from the following table, the deviations from the normal paraffin curve are greater in the case of those series the lower members of which, according to Ramsay and Shields, are characterised by molecular association.

In the great majority of cases the deviations are greatest for the lowest members of a series, the calculated values of Δ being almost invariably higher than the observed, and this may perhaps be explained in the manner suggested by Ramage. I have, therefore, divided each series into two groups, the first ending and the second beginning with the lowest member of the series which contains a CH_2 group linked to two carbon atoms. Thus, of the alkyl chlorides, the first group contains CH_3Cl, CH_3CH_2Cl, and $CH_3-CH_2-CH_2Cl$, and the second group begins with propyl chloride, so that all its members contain one or more $C-CH_2-C$ groups.

In the case of the ethers, esters, and other compounds which contain two alkyl radicals, a series is regarded as homologous when one radical remains unaltered and the other increases by stages of CH_2. The variable radical only is considered in dividing the series into the two groups; thus, although propionic acid contains a $C-CH_2-C$ group, it remains unchanged in the propionic esters, the first group of which consists of methyl, ethyl, and propyl propionate, the second beginning with the last-named ester.

Group	Lower Members		Higher Members	
	Number of Values of Δ	Mean Difference calculated − observed	Number of Values of Δ	Mean Difference calculated − observed
		°		°
Alkyl chlorides	2	+2·70	5	−1·04
„ bromides	2	+1·12	5	−1·25
„ iodides	2	+0·52	3	−1·0
Isoparaffins	—	—	2	+0·57
Toluene, &c.	1	+0·45	3	+0·68
o-Xylene, &c.	1	+6·1	1	−0·5
m-Xylene, &c.	1	+4·25 ?	1	+4·0 ?
p-Xylene, &c.	1	−0·15	1	+0·65
Diethyl benzene, &c.	—	—	1	−0·05
Olefines $H_2C=CHR$	—	—	3	−2·35 ?
„ $RHC=CHR^1$	—	—	3	+0·5 ?
Polymethylenes	—	—	2	−3·85 ?
Ethers	3	+8·2	13	+1·12
Aldehydes	2	+2·0	4	+1·3
Hydrosulphides	2	+3·55	1	−0·5
Amines	2	+8·2	4	+1·7
Esters	47	+4·92	67	+1·53
Associating Substances.				
		°		°
Cyanides	1	+12·65	4	+2·9
Nitro-methane, &c.	2	+11·1	1	+3·85
Ketones	1	+ 6·2	3	+2.85
Fatty acids	2	+ 5·87	7	+1·58
„ alcohols	2	+12·37	5	+5·24

Of the seventeen series of non-associating substances there are only five for which the mean difference between the calculated and observed values of Δ for the higher members exceeds $1^{\circ}{\cdot}5$.

1. The *m*-xylene series. Here there is only one value, which, I think, is doubtful.
2. The olefines, $H_2C=CHR$. Here two of the three individual differences are less than $1^{\circ}{\cdot}5$; the temperatures are all below 0° and are somewhat uncertain.
3. The polymethylenes. The difference for pentamethylene and hexamethylene differs by less than 1° from the calculated value. The B.P. of heptamethylene appears very doubtful.
4. The amines. Differences somewhat erratic; three within $1^{\circ}{\cdot}5$ and two within $0^{\circ}{\cdot}5$. Octylamine and nonylamine clearly incorrect and not included.
5. The esters. Although Ramsay and Shields include these substances as non-associating, there is, I think, reason to suspect slight association.

It will be seen that the differences are greater for associating than for non-associating substances; also that they are greatest for the alcohols and least for the acids, although the factor of association is very high for both these series. In order to arrive at an explanation of these facts the effect of replacing hydrogen by chlorine may first be considered.

The boiling-point of hydrogen chloride is not yet known accurately, but it must be about -80°. Thus, by replacing an atom of hydrogen in the hydrogen molecule by chlorine the boiling-point is raised from $20^{\circ}{\cdot}4$ abs. to about 193° abs., or about 173°. On replacing an atom of hydrogen in methane by chlorine the rise of boiling-point is from $108^{\circ}{\cdot}3$ to $249^{\circ}{\cdot}3$, or 141°. Ascending the series of paraffins the rise of boiling-point due to the replacement of hydrogen by chlorine diminishes rapidly at first, and then more slowly, being only $58^{\circ}{\cdot}5$ in the case of octane. Thus the influence of the chlorine atom becomes relatively smaller as the formula weight of the alkyl group increases.

Consider, now, the effect of replacing a hydrogen atom by a hydroxyl group. In the formation of water from hydrogen gas the boiling-point is raised no less than $352^{\circ}{\cdot}6$, from $20^{\circ}{\cdot}4$ abs. to 373° abs., or in the ratio of $1 : 18{\cdot}3$; in the case of methane the rise is $221^{\circ}{\cdot}8$, from $108^{\circ}{\cdot}3$ to $337^{\circ}{\cdot}7$, or in the ratio of $1 : 3{\cdot}12$; with octane the rise is $65^{\circ}{\cdot}4$, from $398^{\circ}{\cdot}6$ to 464°; and with hexdecane it is only $56^{\circ}{\cdot}5$, from $560^{\circ}{\cdot}5$ to 617°, the ratio being $1 : 1{\cdot}10$.

It will be seen that in the case of hydrogen the influence of the hydroxyl is enormously greater, and in the case of methane very much greater, than that of chlorine in raising the boiling-point, but that on ascending the series of paraffins to octane the influence of the hydroxyl group diminishes until it is little greater than that of the chlorine atom, and it is quite probable that with hexdecane it would be somewhat less. This is, no doubt, to be explained by the fact that the molecules of water and of the lower alcohols are highly associated in the liquid, but not in the gaseous state, and therefore, in order to vaporise the liquids, this molecular attraction must be overcome, and the temperature must therefore be raised. The molecular association diminishes, however, as the series of alcohols is ascended, and is probably slight in the case of octyl alcohol. If so, it would appear that the effect of the hydroxyl group—apart from association—in raising the boiling-point is not very different from, and is probably somewhat less than, that of the chlorine atom, and that the difference between the boiling-points of the lower alcohols and of the corresponding chlorides is entirely due to molecular association in the liquid state.

With the acids there is association in the gaseous as well as the liquid state, and since, according to the tables given by Ramsay and Shields, the factor of association for a liquid fatty acid at its boiling-point is rarely greater, and in most cases is somewhat smaller, than for the corresponding liquid alcohol, the molecular attraction to be overcome on vaporisation must be considerably less for the acid than for the corresponding alcohol, and the resulting rise of boiling-point above the normal value must be less. An explanation of the very low values of Δ for the alcohols and the moderately low values for the acids is thus afforded.

It would take up far too much time and space to give full details of the boiling-points of all the compounds considered, with the observed and calculated values of Δ; but it may, I think, be stated that the difference between the boiling-

point of any non-associating organic compound which contains at least one $C-CH_2-C$ group, and that of its next higher homologue (at any rate up to temperatures of about 300° C.), may be calculated with an error rarely exceeding 1°·5 and generally under 1°, by means of the formula $\Delta = \frac{144{\cdot}86}{T^{0{\cdot}0148\sqrt{T}}}$. The formula seems also to be applicable to any ester which contains at least five atoms of carbon in the variable alkyl or acyl group (the mean error for 40 values of Δ is +0°·93), and with smaller error when the number of carbon atoms is still larger;[1] it is probably also applicable to the higher fatty acids, cyanides, ketones, and nitro-compounds.

Comparison of Molecular Volumes.

The fundamental idea on which both Kopp and Schröder based their methods of calculating the molecular volumes of organic compounds from the atomic volumes of the component elements was the constancy of the increase in molecular volume for each addition of CH_2. With regard to this point the question was greatly discussed whether the comparison should be made at the same temperature, say 0° C., or at the boiling-points of the compounds under the same pressure. Later, when Van der Waals brought forward his conception of corresponding states, it was thought probable that the comparison should be made at *corresponding* or equal *reduced* temperatures; that is to say, at temperatures which bear the same ratio to the critical temperatures. If the generalisations of Van der Waals were strictly true, the boiling-points under corresponding pressures would be corresponding temperatures, but that is not usually the case. The comparison may, therefore, be made either at equal reduced temperatures or at the boiling-points under equal reduced pressures; or, lastly, it may be made at the critical points themselves, and, thanks to the law of Cailletet and Mathias, the critical volumes can be ascertained with a great degree of accuracy.

In order to find whether the difference in molecular volume for each addition of CH_2 is really constant it is best to examine such perfectly normal substances as the paraffins, and the data for four consecutive members of the series—*n*-pentane, *n*-hexane, *n*-heptane, and *n*-octane—are fortunately available.

In the table below the molecular volumes and the differences, Δ, for an addition of CH_2 are given under the following conditions:[2]—

A. At 0° C.
B. At the respective boiling-points under 1 atm. pressure.
C. At equal reduced temperatures (0·6396).
D. At the respective boiling-points under equal reduced pressures (0·02241).
E. At the respective critical points.

Paraffin	A		B		C		D		E	
	M. Vol.	Δ	M. Vol.	Δ	M. Vol.	Δ	M. Vol.	Δ	M. Vol.	Δ
n-Pentane	111·33		117·80		116·13		116·13		309·3	
		15·44		22·13		20·09		21·06		56·8
n-Hexane	126·77		139·93		136·22		137·19		366·1	
		15·69		22·63		20·18		21·49		60·2
n-Heptane	142·46		162·56		156·40		158·68		426·3	
		15·88		23·70		20·54		21·83		62·6
n-Octane	158·34		186·26		176·94		180·51		488·9	

[1] Thus the observed B.P. of *n*-hexyl formate is 153°·6, and the value of Δ calculated from the formula is 22·8, giving 176°·4 as the B.P. of the next higher homologue. This agrees very well with the observed B.P. of *n*-heptyl formate, 176°·7, but not with that of *n*-hexyl acetate, 169°·2. Again, the observed B.P. of methyl caproate (hexoate) is 149·6, and the calculated value of Δ is 23°·0, giving 172°·6 as the B.P. of the next homologue. The observed B.P. of methyl œnanthylate (heptoate) is 172°·1, but that of ethyl caproate is only 166°·6.

[2] The atomic weights [C=11·97, H=1] employed in the original papers are retained.

It will be seen that in every case there is a decided rise in the value of Δ as the series is ascended, but that the rise is relatively smallest when the comparison is made at the particular reduced temperature chosen. At higher reduced temperatures, however, it would be relatively much greater, since it is very marked at the critical point, where the reduced temperature = 1. The rise is also comparatively small at the common temperature 0°, but the comparison would not be satisfactory if a higher common temperature, say 150°, were chosen, because the coefficients of expansion differ considerably; at 150° the values of Δ would be 8·75, 13·45, and 15·38 respectively.

In the case of nine of the lower esters the values of Δ are by no means constant, whether the comparison be made at 0°, at the boiling-point, or at the critical point. The eleven values of Δ vary in the three methods between 16·34 and 18·21, 20·84 and 23·42, 54·3 and 61·7 respectively; but there is not a regular rise with increase of molecular weight.

Both Kopp and Schröder compared the molecular volumes of compounds at their boiling-points under normal pressure, but they deduced quite different values for the atomic volumes of carbon and hydrogen; it is clear, however, that as Δ varies considerably no values whatever for C and H could give accurate results, even in the case of true homologues.

Traube makes the comparison at a common temperature, usually 15°, and takes into consideration both the actual volumes of the molecules and the co-volume, which he assumes to have the same value, $24·5\ (1+at)$, where $a=1/273$, for all substances. He calculates definite values for the atomic volumes of C and H at a given temperature; thus, at 15°, $C=9·9$ and $H=3·1$, or $CH_2=16·1$, so that here again the difference for CH_2 at a given temperature should be constant.

It does not appear to me that the problem has yet been completely solved, although Traube's method of calculation generally gives much better results than those of Kopp and Schröder.

Comparison of Boiling-points at a Series of Equal Pressures.

The results of this comparison are often exceedingly simple if the two substances compared are very closely related, and if there is no molecular association in either case. Taking, for example, chlorobenzene and bromobenzene, it is found that the ratio of the boiling-points (on the absolute scale of temperature) under equal pressures is constant whatever the pressure may be, or

$$\frac{T_A}{T_B}=\frac{T'_A}{T'_B}=1·0590.$$

A similar result is obtained with the other halogen derivatives of benzene, with ethyl bromide and ethyl iodide, with ethyl acetate and propyl acetate, and some other pairs of esters; but in some cases of close relationship—for example, with ethyl formate and ethyl acetate—the ratio is not quite constant, and the formula becomes $\frac{T_A}{T_B}=\frac{T'_A}{T'_B}+c(T_B-T'_B)$, where c has a very low value [0·0000417 for these two esters]. When there is no close relationship, but the molecules are not associated, the value of c is usually larger—for example, 0·0001185 for carbon disulphide and ethyl bromide.

Lastly, when there is no close relationship and the molecules of one or both substances are associated, the formula $\frac{T_A}{T_B}=\frac{T'_A}{T'_B}+c(T_B-T'_B)$ may no longer hold, and a third term may be required, thus: $\frac{T_A}{T_B}=\frac{T'_A}{T'_B}+c(T_B-T'_B)+d(T_B-T'_B)^2$; or, in any case, the value of c becomes much higher, as with benzene and ethyl alcohol [$c=0·0008030$] or sulphur and carbon disulphide [$c=0·0006845$].

Behaviour of Liquids when Mixed together.

There are three points to consider when two liquids are brought together—(1) their miscibility, whether infinite, partial, or inappreciable; (2) the relative volumes of the mixture and of the components; (3) the heat evolved or absorbed.

Liquids which are classed as non-miscible rarely, if ever, bear any close chemical relationship. Thus water is practically non-miscible with all hydrocarbons and with their halogen and many other derivatives; again, mercury, so far as I know, is not miscible with any liquid compound, organic or inorganic. It is true that the higher aliphatic alcohols are almost insoluble in water, although there may be said to be some chemical relationship between them, inasmuch as an alcohol may be regarded as an alkyl derivative of water. But the alcohols may also be looked upon as hydroxyl derivatives of the hydrocarbons, and, the higher the formula weight of the alkyl group, the greater is its influence, relatively to that of the hydroxyl, on the properties of the alcohol. Thus, while the lower alcohols show considerable resemblance to water—for example, in their behaviour with dehydrating agents, such as sodium, phosphoric anhydride, or lime, and in their power of uniting with metallic salts to form crystalline alcoholates corresponding to the hydrates—this resemblance diminishes as we ascend the series, and is generally not observable with the higher members.

On the other hand, the higher the molecular weight of the alcohol the closer is its resemblance to the hydrocarbon from which it is derived. This, as already mentioned, is well shown by the diminishing difference between the boiling-points of the alcohol and paraffin as the series is ascended; it may also be noted that methane was long classed as a permanent gas, while methyl alcohol is a liquid; whereas both hexdecane ($C_{16}H_{34}$) and cetyl alcohol ($C_{16}H_{33}OH$) are solids, the former melting at 18° and the latter at 50°.

It may, in fact, I think, be stated that the chemical relationship between water and methyl alcohol is fairly close, while that between water and cetyl alcohol is very distant. So, also, two adjacent members of a homologous series, such as methyl and ethyl alcohol, are more closely related than two members of widely different molecular weight, such as methyl and cetyl alcohol.

Adopting this view, it is, I believe, safe to state that liquids which are chemically closely related to each other are invariably miscible in all proportions.

As regards the relative volumes of a mixture and of its components at the same temperature, it is well known that inequality is the rule and equality the exception; and, further, that contraction is more frequently observed than expansion on admixture. So far, however, as experimental evidence is available, it appears that when the liquids are very closely related to each other the change of volume is exceedingly small. For example, with ethyl acetate and propionate in equimolecular proportions, + 0·015 per cent.; toluene and ethyl benzene, − 0·034 per cent.; *n*-hexane and *n*-octane, − 0·053 per cent.; methyl and ethyl alcohol, + 0·004 per cent.; chlorobenzene and bromobenzene, no change.

When the relationship is less close the changes are usually, but not invariably, larger, and are in some cases positive, in others negative; and it is rarely possible, in the present state of our knowledge, to predict from the nature of the substances—unless one is basic and the other acidic in character—whether contraction or expansion is to be expected. Thus, when methyl alcohol is mixed with water considerable contraction occurs, although the relationship is less close than between methyl and ethyl alcohol, which expand to a minute extent on mixing.

All we can say with regard to the alcohols is that, the higher the molecular weight—or, if isomeric alcohols are included, the higher the boiling-point—the smaller, as a rule, is the contraction on mixing with water.

Very similar remarks apply to the heat changes which occur on mixing liquids. It appears that in the case of very closely related substances these changes are exceedingly small, or negligible, as is indicated by the very minute change of temperature which has been observed, thus: ethyl acetate and propionate, − 0°·02; toluene and ethyl benzene, + 0°·05; *n*-hexane and *n*-octane, + 0°·06; methyl and ethyl alcohol, − 0°·10; chlorobenzene and bromobenzene, 0°·00.

It might be expected that in the case of less closely related substances contraction would be accompanied by evolution of heat and expansion by absorption of heat, but this is by no means invariably the case; for example, on mixing 40 gram-molecules of propyl alcohol with 60 gram-molecules of water there is a contraction of 1·42 per cent., but a fall of 1°·15 in temperature was observed. Taking the alcohols as a group, it is found that, the higher the boiling-point, the smaller is the heat evolution or the greater the absorption on admixture with water.

Properties of Mixtures.

The behaviour of two non-miscible liquids when heated together is well known, and I need only refer to the fact that the vapour pressure is equal to the sum of the vapour pressures of the pure components at the same temperature; that the boiling-point is the temperature at which the sum of the vapour pressures of the components is equal to the pressure under which the liquid is being distilled, provided that evaporation is taking place freely and the vapour is not mixed with air; and, lastly, that the composition of the vapour is independent of that of the liquid (so long as both components are present in sufficient quantity), and is expressed by the equation $\frac{x_A}{x_B} = \frac{P_A D_A}{P_B D_B}$, where x_A and x_B are the relative weights of the two components in the vapour, P_A and P_B their vapour pressures at the observed boiling-point, and D_A and D_B their vapour densities.

The vapour pressure, boiling-point, and vapour composition, then, can be calculated for non-miscible liquids, and it has been stated that such liquids have never any close chemical relationship, and are usually not related at all.

On the other hand, it has been mentioned that when the chemical relationship is very close the liquids are invariably miscible in all proportions, and that there is very little, if any, volume or heat change on admixture.

So, also, the vapour pressure and boiling-point of a mixture of closely related liquids are easily ascertained from those of the pure components, and the composition of the vapour bears a simple relation to that of the liquid.

The vapour pressure of the mixture is given, at any rate with a very close approach to accuracy, by the equation $P = \frac{mP_A + (100 - m) P_B}{100}$, where P, P_A and P_B are the vapour pressures of the mixture and of the components, A and B, at the observed boiling-point, and m is the molecular percentage of A.

Van der Waals concluded from theoretical considerations that this relation should be true when the critical pressures are equal and the molecular attractions agree with the formula proposed by Galitzine and by D. Berthelot, $a_{1\cdot2} = \sqrt{a_1 \cdot a_2}$, where $a_{1\cdot2}$ represents the attraction of the unlike molecules and a_1 and a_2 the respective attractions of the like molecules. That is certainly the case with chlorobenzene and bromobenzene, which, as already mentioned, show no heat or volume change on admixture, for the maximum difference between the observed and calculated pressure in three experiments was less than 0·1 per cent.

But the relation is, at any rate, very nearly true for closely related substances when the critical pressures are not equal, for in the case of methyl and ethyl alcohol the difference between the observed and calculated pressure was within the limits of experimental error, and with four other pairs of closely related substances the greatest mean difference (for three readings each) was only 0·6 per cent. It is not, however, as Speyers suggested, true for all non-associated substances, whether closely related or not; indeed, chemical relationship seems to be much more important than the state of molecular aggregation, for the relation is true for methyl and ethyl alcohol, while it is altogether untrue for benzene and hexane.

The boiling-point of a mixture of closely related liquids may be ascertained from the vapour pressures of the components, but not so simply as in the case of non-miscible liquids, because the boiling-point depends on the composition of the liquid.

In order to calculate the boiling-points of all mixtures of two closely related liquids under normal pressure we should require to know the vapour pressure of each substance at temperatures between their respective boiling-points under that pressure. Thus, chloroform boils at 132°·0, and bromobenzene at 156°·1, and we must be able to ascertain the vapour pressure of each substance between 132° and 156°.

The percentage molecular composition of mixtures which exert a vapour pressure of 760 mm. must then be calculated at a series of temperatures—say every two degrees—between these limits by means of the formula $m = 100 \cdot \frac{P_B - P}{P_B - P_A}$, where, in this case, $P = 760$.

Lastly, the molecular percentages of A, so calculated, must be mapped against the temperatures, and the curve drawn through the points will give us the required relation between boiling-point and molecular composition under normal pressure. In the case of six pairs of closely related liquids the greatest difference between the observed temperature and that read from the curve constructed as described was 0°·27.

For liquids which are not closely related the differences are usually much greater, and particular mixtures of constant (minimum or maximum) boiling-point are not unfrequently met with, especially when the molecules of one or both substances are associated in the liquid state.

The formula for the composition of the vapour from a mixed liquid suggested independently by Berthelot and by Wanklyn, $\frac{x_A}{x_B} = \frac{W_A P_A D_A}{W_B P_B D_B}$ (where x_A and x_B, P_A and P_B, D_A and D_B, have the same meaning as in the equation for non-miscible liquids, and W_A and W_B are the relative weights of the two components in the liquid mixture), was shown by F. D. Brown to be incorrect, and he proposed the simpler formula, $\frac{x_A}{x_B} = c\frac{W_A}{W_B}$, where c is a constant which does not differ greatly from $\frac{P_A}{P_B}$. The subject was investigated mathematically by Duhem and by Margules, and experimentally and mathematically by Lehfeldt and by Zawidski. The two last-named observers deduced workable formulæ from the fundamental equation of Duhem and Margules, and it is noticeable that both Lehfeldt's and Zawidski's formulæ, in their simplest form, become identical with Brown's. Zawidski's, however, assumes the form $\frac{x_A}{x_B} = \frac{P_A}{P_B} \cdot \frac{W_A}{W_B}$. This formula is certainly not, as a rule, true for mixtures of liquids which are not closely related; but, on the other hand, in the very few cases examined the equation $\frac{x_A}{x_B} = c \cdot \frac{W_A}{W_B}$ appears to hold for those mixtures for which the equation $P = \frac{mP_A + (100 - m)P^B}{100}$ is true; that is to say, generally, for closely related liquids.

The question, however, whether $c = \frac{P_A}{P_B}$ is an open one; but it is interesting to remark that if this equality holds it should be possible in many cases to calculate the vapour pressure at any temperature, the boiling-point under any pressure, and the composition of the vapour, of any mixture of two very closely related liquids, if the boiling-point of one of them under any one pressure, and the vapour pressures of the other within sufficiently wide limits of temperature, are known. For the boiling-points on the absolute scale of the two liquids at the same pressure bear a constant ratio to each other, or $\frac{T_A}{T_B} = \frac{T'_A}{T'_B}$; hence the vapour pressures or boiling-points of one substance can be calculated if those of the other are known. Again, from the vapour pressures of the pure substances we can calculate the vapour pressures and the boiling-points of all mixtures; and, lastly, if $c = \frac{P_A}{P_B}$, we can make use of Brown's formula, $\frac{x_A}{x} = \frac{W}{W}$, to calculate the composition of the vapour from

all mixtures without carrying out special experiments to find the value of c. It is, therefore, a matter of considerable interest to ascertain whether c is really equal to $\frac{P_A}{P_B}$ or not.

When the equation $P = \frac{mP_A + (100-m)P_B}{100}$ does not hold good, a modification of Brown's formula, or that of Lehfeldt, or of Zawidski, must be employed to calculate the vapour composition, and the constants for those formulæ must first be determined experimentally.

Other physical properties, such as the refractive power of mixtures, might be considered, but I will only refer to the critical temperature and pressure. In 1882 Pawlewski stated that the critical temperature of a mixture could be calculated from those of the components by the formula $\theta = \frac{m\theta_A + (100-m)\theta_B}{100}$, where m is the percentage *by weight* of A; and G. C. Schmidt, in 1891, carried out experiments to test the correctness of the statement, purposely choosing substances of widely different physical properties. The differences between the calculated and observed temperatures were not, as a rule, very great, rarely exceeding 4°, and Schmidt considered that they might, to some extent, be accounted for by partial decomposition of one or other component.

Such determinations are, however, liable to serious errors. It is exceedingly difficult to fill a tube with the required amount of a liquid mixture of known composition quite free from air, and, although the composition of the very small amount of liquid employed might be determined after the experiment from its specific refractive power, it would be necessary to know the specific refractive powers of the two components and of mixtures of them. Schmidt does not state how he prepared his mixtures and determined their composition.

Again, when a liquid mixture is heated in a sealed tube, fractionation goes on, so that the more volatile component tends to accumulate in the upper part of the tube, leaving the less volatile component in excess below, and unless a stirring arrangement, such as that devised by Kuenen, is employed, many hours would elapse before complete admixture by diffusion took place at the critical point.

By far the most important and accurate experiments on this subject have been carried out by past or present pupils of Professor Kamerlingh Onnes, notably by Professor Kuenen; and it is quite certain that the formula of Pawlewski cannot be generally true for mixed liquids, for, just as we may have mixtures of minimum or maximum boiling-point, so also, as Kuenen has shown, mixtures of minimum or maximum critical temperature may exist. Thus the critical temperature of carbon dioxide is 31°·1, and of ethane, 32°·0, but that of a mixture containing 30 molecules per cent. of carbon dioxide is 18°·8. The question remains, however, whether some such law as that proposed by Pawlewski may not hold good for closely related substances. In certain cases, when the relationship is very close (for example, C_6H_5Cl and C_6H_5Br), the critical pressures are equal, or very nearly so, and it seems probable that the critical pressure would be the same for any mixture as for the components. Such a case as this would be likely to give the simplest possible relation between the critical temperatures of a mixture and those of its components; and although the critical temperatures of these substances are inconveniently high, there are, no doubt, others which might be employed—perhaps ethyl chloride and bromide, or possibly carbon dioxide and carbon disulphide. I imagine, however, that Pawlewski's formula would be more likely to hold if m represented the *molecular percentage*, and not the percentage *by weight* of A.

In the case of homologous compounds, paraffins, ethers, esters, and so on, the critical pressures are not equal, and it would be necessary to find whether the critical pressures of mixtures are represented by the formula $P = \frac{mP_A + (100-m)P_B}{100}$ (where m is the molecular percentage of A), and also whether any such simple formula is applicable to the critical temperatures.

Kuenen has made some observations with mixtures of ethane and butane containing 2·5 and 5 molecules per cent. of butane, and at the conclusion of his paper

he says: 'If there was a simple law connecting the critical constants of mixtures with those of the constituents, we might calculate the constants for the second substance [those of the first being known]. But such is not the case. Pawlewski's law that the critical temperature is proportional to the composition, expressed in weight units, is very inaccurate, the deviations being sometimes considerable in both directions.'

It would, I think, be of great interest if Professor Kuenen could find time to carry out further experiments with mixtures of ethane and butane in order to settle this point, or, perhaps, with *n*-hexane and *n*-octane, both of which can be more easily obtained in a pure state.

From what has been said it may be concluded that, in order to ascertain the normal behaviour of pure substances under different conditions, or to find the simplest relations between the boiling-points, molecular volumes, or other physical constants of a series of substances, or, again, to ascertain the normal behaviour of substances when mixed together, and the properties of the mixtures as compared with those of the components, it is undoubtedly advisable—at first, at any rate—to confine our attention to substances of which the molecules show no signs of association in either the gaseous or liquid state.

In the case of mixtures it is also best to begin with substances which are chemically closely related to each other.

The following Papers and Report were read :—

1. *The Relation between the Crystalline and the Amorphous States as disclosed by the Surface Flow of Solids. By* G. T. Beilby.

In former papers the phenomena observed in connection with the flow of solids have been fully described, and in the most recent of these the results of the observations have been applied to the study of the hard and soft states in metals. The purpose of the present paper is to direct attention to the very general character of the relations which have been found to exist between the amorphous and the crystalline states.

Observations on flow in crystalline substances are described and illustrated by photo-micrographs. By the use of etching in stages the successive layers of a polished or disturbed surface are disclosed, from the smooth vitreous surface, through a granular layer, to the undisturbed crystalline body beneath. The demonstration that the polish of a lens of rock crystal has resulted from the formation of a flowed layer of amorphous phase on its surface suggests that no crystalline substance is too hard to yield to the mechanical flowing action.

The passage of the amorphous back to the crystalline state by the agency of heat is discussed, and attention is directed to the important bearing of the fact that this transformation occurs at a definite temperature, on the behaviour of solids at ordinary atmospheric temperatures. It is suggested that as the stability point of ice is probably a long way below the freezing point, the amorphous phase can only have a transient existence at ordinary atmospheric temperatures; while at the lower range of winter temperatures within the Arctic Circle, the amorphous phase, once formed, may be stable and permanent.

The grinding of crystalline substances to powder does not simply consist in their reduction to finer and finer crystalline fragments, but it involves the transformation of at any rate a part of the substance into the amorphous condition.

When crystalline powders are formed into cakes by pressure the cementing material is the amorphous phase which results from flow.

In metals, and probably in most other solids, the physical and other properties of the two phases are so distinct that it is not difficult to determine the transition temperature or stability point in the transformation A → C.

From the existence of a definite stability point it is argued that not only must all crystalline substances be capable of existing in the amorphous as well as in the crystalline state, but that, by purely mechanical means, it is possible to transform them into this state.

These observations, and the conclusions to which they have led, have a very direct bearing on the flow of rocks. The recognition of the transformation from crystalline to amorphous through an intermediate mobile phase, for the first time supplies an explanation of why flow which has been started by stresses can cease while the disturbing stresses are still maintained.

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2. *The Action of certain Gases on Glass in the Neighbourhood of Hot Metals.* *By* G. T. BEILBY.

In a former paper ('British Association Report, 1903') the formation of halos of decomposed glass around pieces of metal placed on glass plates and heated in a muffle to which the products of combustion had access was described. Further experiments and observations have been made to ascertain (1) To what chemical agent is the decomposition of the glass due? and (2) What is the cause of the localisation of this decomposition in the immediate neighbourhood of the hot metal as shown in the formation of halos and images?

By passing various gases over heated glass slips on which pieces of metal foil were placed, it was found that the most active agents in the decomposition of the glass were sulphur dioxide, air, and water vapour.

The decomposition products of the glass were ascertained to be sodium or potassium sulphate and silica.

In the original experiments, in which the products of combustion had access to the muffle, the source of the SO_2 was the trace of sulphur compounds in the coal gas used for heating. The actual attack on the glass is made by sulphur trioxide formed by the oxidation of the SO_2.

The dull white film frequently seen on the outside of tubes or other glass vessels which have been heated in a gas furnace or muffle is no doubt due to the decomposition of the glass by the combustion gases.

The second question, as to the cause of the localisation of the decomposition, cannot be answered so conclusively as the first. The active agent being SO_3, the suggestion naturally occurs that its formation from SO_2 and air is accelerated by the presence of the hot metal, which acts as a catalyte.

The question was discussed whether in this case the combination of these gases takes place on the surface of the metal or whether it takes place to some extent in the surrounding atmosphere. The appearances suggest that the agent which caused the decomposition had been in the form of a definite cloud of particles shot out from the metal surface rather than in the form of widely diffused molecules of SO_3 in a very large volume of air. While no traces of metal could be detected in the halos or images, it does not seem necessary to suppose that the particles thrown off by the metal must be either visible or ponderable in order that they may produce very powerful effects.

It cannot be claimed that these observations give a final answer to the second question proposed; but they certainly do not give a final negative to the suggestion that some part of the effect may be due to the slow disintegration of the metal.

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3. *On the Formation of Salts in Solutions, especially amongst Tautomeric Compounds.* *By* Professor J. W. BRÜHL.

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4. *Methods of Investigating Alloys, illustrated from the Copper-Tin Series.* *By* C. T. HEYCOCK, *F.R.S., and* F. H. NEVILLE, *F.R.S.*

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5. *Hexachlor-α-Picoline and its Derivatives.* *By* W. J. Sell, *M.A., F.R.S.*

With the object of assisting in the orientation of some of the lower chloro and other derivatives of pyridine it was thought advisable to study the action of chlorine on the hydrochlorides of various methylpyridines. The substance employed to begin with was α-picoline after purification of its double salt with mercuric chloride.

The chief solid product of the chlorination of α-picoline is a white crystalline substance having the formula C_6HCl_6N, and which readily gives trichlorpicolinic acid on heating with 80 per cent. sulphuric acid; it therefore contains the fully chlorinated methyl group CCl_3, which, as usual, breaks down to COOH with elimination of HCl.

Trichlorpicolinic acid when distilled with glycerine is readily resolved into a trichlorpyridine (m.p. 72–3°), first obtained by Keiser, and described by him as the hydrochlorate of a dichloropyridine, but since shown by Sell and Dootson to be a trichlorpyridine. The positions of the chlorine atoms in this compound are unknown, but various considerations lead to the supposition that they occupy the positions 3, 4, 5.

To prove that this is so, recourse was had to the synthesis from the trichlorpicolinic acid of a compound whose constitution is established. Such a substance is 2-amino-3, 4, 5-chlorpyridine. The trichlorpicolinic acid was converted into the amide, and this into the amino derivative by the Hofmann reaction. On comparison the aminotrichlorpyridine was found to be identical with the 2-amino-3, 4, 5-trichlorpyridine obtained from other sources.

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6. *The Change of Conductivity in Solutions during Chemical Reactions.* *By* P. V. Bevan, *M.A.*

The experiments described in this paper were made to determine, if possible, the part played by the hydrogen ions of the acid used in the inversion of cane sugar. The object was to attack the problem of catalytic action by applying the Kohlrausch method of determining the conductivity of the solution. It seemed certain that, the action being conditioned by the presence of the hydrogen ions, their capacity as carriers of the current must be affected, and so it was thought that some light might be thrown on the actual mechanism of the action. If the resistance of a solution of cane sugar with a small percentage of hydrochloric acid be obtained at various stages of the inversion, a change of resistance, which may amount to 10 or more per cent. of the initial resistance, occurs during the inversion. Two factors which contribute to this change are the loss of water during the inversion and the change of the ionic viscosity of the solution consequent on the transition from the cane to the inverted sugar. The results so far obtained have not enabled me to discriminate between the various causes producing the total effect. Another series of experiments was made determining the conductivity of solutions containing a constant quantity of sugar per volume but a varying amount of acid. On plotting the concentration (HCl) and specific molecular conductivity one obtains a curve, which at concentrations down to about ·005 normal is a straight line parallel to the concentration axis, but for concentrations lower than this the curve drops towards the concentration axis; the specific molecular conductivity decreasing at a concentration of ·0002 normal, there are indications that the curve becomes again parallel to the axis of concentration. At this small concentration, however, the observations so far made are not very consistent, and at present stress is not laid on this point. The experiments show in this way an effect on the molecular conductivity, which can be explained by supposing the H-ions are loaded up, forming the centre of a group consisting of one or more sugar molecules and one or more water molecules. This kind of group need not be considered as a stable compound, but may be merely in a state where it can split easily into water and cane sugar again, or in some cases

into the invert sugars. At higher concentrations than the value at which the specific molecular conductivity becomes constant the proportion of H-ions loaded in this way is small at any particular time; hence we see that we may explain on these lines the influence of concentration of the sugar on the rate of inversion.

Further experiments are in progress, and it is hoped that experiments on the actual velocity of the ions in the inversion with dilute acid may lead to some definite results.

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7. *On Double Acetylides.*
By Major A. E. Edwards *and* Professor W. R. Hodgkinson, *Ph.D.*

The authors have investigated the action of acetylene on a number of salts with a view to obtaining an explosive of a sufficiently safe nature to be used for military purposes, and referred in this paper to some silver compounds which they have obtained. The acetylene employed was purified as well as possible from sulphur and phosphorus compounds, and was then brought in contact with silver salts in solution or suspended in boiling water. In some cases the gas was passed for some days continuously through the water containing the suspended salts.

A number of organic salts, such as silver acetate, benzoate, and butyrate, yield the same acetylide as that obtained from neutral or faintly alkaline silver nitrate solution. A solution of silver nitrate in nitric acid of 1·3 sp. gr. did not give this particular acetylide, but one containing nitric acid as nitrate. Solutions of silver salts in potassium cyanide or in thiosulphate are quite unaffected by acetylene, but pure thiocyanate suspended in water is acted upon; the product in this case is explosive, and contains both sulphur and cyanogen, but was not obtained in a pure state.

The following compounds have been obtained in a definite form, analysed and examined as to their sensitiveness to percussion and heat.

From a boiling solution of silver bichromate acetylene precipitates an orange-red salt of the composition ($Ag_2OC_2H_2,Ag_2CrO_4$), whilst chromic acid is liberated. When dry, this substance is very sensitive to friction, and explodes violently at 157° C. Corresponding compounds are formed from silver sulphate, selenate, tungstate, and molybdate; they are all much less sensitive than the chromic acid compound, and explode much more feebly.

Compounds from the phosphate and vanadate were obtained with difficulty, and no satisfactory analyses were made; they explode in a very feeble but peculiar manner.

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8. *On some Reactions between Ammonium Salts and Metals.*
By Professor W. R. Hodgkinson, *Ph.D., and* Arthur H. Coote.

As far back as 1879 a note was published by one of us on the action of aluminium on ammonium chloride, and we have recently continued the investigations of the behaviour of ammonium salts generally towards metals.

Ammonium nitrate, either in aqueous solution or in a fused state, acts very vigorously on some metals.

There is a notable difference, as a rule, between the fused salt and its aqueous solution in regard to rate of action on the more common metals; but in the case of the metal cadmium there is little difference perceptible between the rate of action of an aqueous solution and the melted salt. Cadmium placed in an ice-cold saturated solution of ammonium nitrate rapidly dissolves without evolution of gas. The liquid becomes alkaline from presence of a little free ammonia; the solution gives off nitrogen only when heated to 100°, when the cadmium ceases to dissolve and some remains in excess. The solution contains a little free ammonia, and apparently the nitrite of cadmium and ammonium. This is, at any rate, indicated by the fact that every trace of cadmium can be precipitated from this solution by passing through it a stream of carbon dioxide at the ordinary temperature. The solution contains mainly ammonium nitrite.

Zinc and magnesium act in a similar manner, but, owing to the formation of somewhat insoluble double ammonium compounds, not to the same extent or with the rapidity observed with cadmium. Aluminium, iron, mercury, and silver are unaffected by an aqueous solution of the salt, but nickel, copper, and lead are slightly active. Lead becomes coated with a somewhat insoluble nitrite.

Melted ammonium nitrite has no action on iron, mercury, or aluminium, and, in fact, these metals are quite unaffected when the salt is heated with them so strongly as to decompose with formation of red fumes; under these conditions silver is slightly attacked. Approximately it may be stated that when the salt is *just fused* the following metals are acted upon at rates about in the order given: cadmium, magnesium, zinc, copper, nickel, lead, bismuth.

The mechanism of the reaction as regards cadmium and *fused* ammonium nitrate seems to be that first a little ammonia is split off and then a metallic nitrate formed. This, however, involves the expulsion of hydrogen, which in turn reduces the nitrate of the metal to nitrite, which immediately reacts with the ammonium salt in the usual manner, liberating nitrogen.

Weighed quantities of metals have been allowed to act upon ammonium nitrate in a vacuum-tube maintained at the melting-point of the salt. In the cases of cadmium and copper the gas collected was pure nitrogen; with cadmium the amount of nitrogen collected falls a little short of 4 atoms of nitrogen to 1 atom of metal; with copper it is nearly 3 atoms of nitrogen to 2 atoms of the metal. The amount of ammonia liberated in the first phase of the reaction may have something to do with this deficit of nitrogen, but we are unable to explain it fully at present.

Powdered cadmium dissolves in a solution of aniline nitrate, and if the temperature be maintained below 10° no appreciable evolution of gas occurs, and a considerable yield of diazoaminobenzene is obtained. The course of the reaction is very similar to that with the ammonium salt, a little aniline being liberated in the first instance.

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9. *Report on the Study of Hydro-aromatic Substances.*— See Reports, p. 60.

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10. *The Constitution of Nickel Carbonyl.* *By* H. O. JONES, *M.D.*, *D.Sc.*

The study of the chemical reaction of nickel carbonyl, first undertaken in association with Professor Sir James Dewar, has been continued and extended.

Nickel carbonyl reacts readily with hydroxylamine in alcohol solution to give a bluish violet-coloured gum which solidifies on standing in a desiccator, is insoluble to all solvents, and is decomposed by water and acids and on heating to 100° C. The action of water and of heat on the compound gives rise to new compounds similar in appearance to the original substance, and which react with acids, giving nickel and hydroxylamine salts and carbon dioxide.

These compounds have not been obtained pure enough to give analytical results of any value, but the ratio Ni : NH_2OH in the original compound is found to be 1 : 4–5, and is probably 1 : 4.

Hydrazine hydrate reacts in a similar way, and gives a blue-violet solid compound.

The formation of these substances shows that nickel carbonyl can react as a ketonic compound.

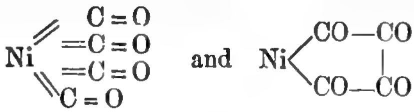
Nickel carbonyl reacts with the alkyl magnesium iodide compounds of Grignard, in some cases violently, to produce dark-coloured oily and solid substances, which contain nickel, magnesium, and iodine, and are decomposed by acids, yielding a mixture of compounds.

The product obtained from several aliphatic iodides has been examined, but no pure compound has hitherto been isolated and identified. Some of the compounds produced react with sodium bisulphite, hydroxylamine, and substituted hydrazines, and are very probably ketonic.

The product of the action of phenyl magnesium iodide on nickel carbonyl

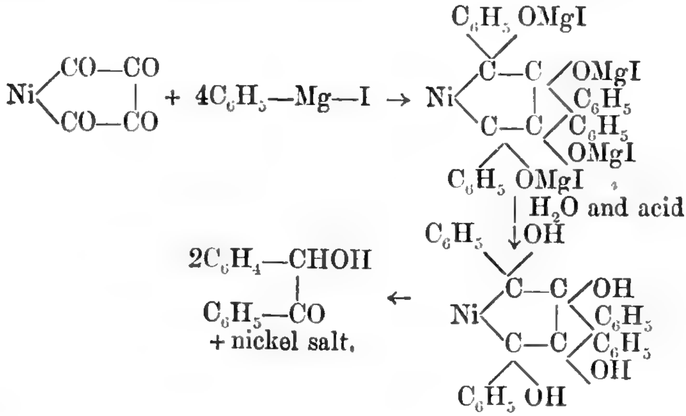
when treated with acids gave rise to a mixture which was found to consist chiefly of *diphenyl* and *benzoin*. The former is very readily produced from phenyl magnesium iodide, and is frequently observed among the products of its reactions. The formation of benzoin has an important bearing on the constitution of nickel carbonyl.

All the reactions of nickel carbonyl which have been described previously can be equally well explained by means of either of the two formulæ

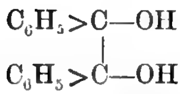


which have been proposed; but benzoin could be produced in a much simpler way from a compound with the second formula. Its production may therefore be regarded as evidence in favour of this.

The following suggestion as to the course of the reaction is to be regarded as purely tentative:—



The product



is supposed to undergo molecular transformation into benzoin.

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11. *A Suggested Explanation of the Phenomena of Opalescence observed in the Neighbourhood of Critical States.* *By* F. G. Donnan.

It has been frequently observed (Guthrie, Rothmund, Friedländer, Konowalow) that a mixture of two liquids becomes opalescent before the temperature is reached at which definite separation into two phases occurs. Similarly, a mixture of two partially miscible liquids remains opalescent at temperatures beyond that corresponding to the disappearance of the meniscus. Apparently analogous phenomena have been noticed in the case of one-component liquid-vapour systems, especially by Wesendonck and Teichner. The latter has observed the existence of permanent opalescent states in the case of carbon tetrachloride at temperatures several degrees higher than the critical. These phenomena, so far as they refer to mixtures of liquids, have been studied by Konowalow, who considers that they are due to a partial separation into two phases, occurring round dust-nuclei acting as centres of disturbance. Konowalow shows that such a disturbance of equilibrium in the otherwise homogeneous liquid will, in the neighbourhood of the critical solution temperature, involve only a slight expenditure of work owing to the small change of vapour-pressure with composition under these conditions.

The author suggests another explanation, which involves the following suppositions:—

(*a*) Below the critical temperature the interfacial tension between the two phases is positive for all values of the radius of curvature.

(*b*) At the critical temperature the interfacial tension becomes zero for all ordinary curvatures, but remains positive for very small values of the radius of curvature. It will be seen that this assumption involves the further one, that at the temperature of disappearance of the meniscus at a bounding surface of ordinary curvature (critical temperature) the two phases do not become identical.

(*c*) At temperatures slightly above the critical the interfacial tension is still positive for very small radii of curvature, but negative for all ordinary curvatures.

(*d*) At still higher temperatures the interfacial tension becomes negative for all curvatures.

These assumptions carry with them the main assumption that the interfacial tension between two liquid phases increases in general with diminution of the radius of curvature of the bounding surface. This increase, however, need not extend to the very smallest values of the radius of curvature. It is also necessary to suppose that the curve connecting interfacial tension with radius of curvature of the bounding interface suffers a shift towards the region of negative values of the interfacial tension as the temperature rises.

Granting these assumptions, the existence of permanent opalescent states above the ordinary critical point follows at once. For it can be shown that the conditions specified, for example, under (*c*) would produce a system in which one phase would be distributed throughout the other in a state of very fine subdivision. If the particles are small enough, such a system would not present a milky appearance, but would doubtless be opalescent.

An interesting question concerning the nature of the critical state is thus raised—namely, as to whether there is not sufficient experimental evidence to justify the belief that the passage of systems through critical states is insufficiently described by the simple theory of Andrews? That is the wider question at issue. The particular form of explanation suggested in the present paper also raises the question as to whether the observed phenomena may not admit of interpretation by taking into consideration the operation of capillary forces?

These points seem worthy of discussion, especially in relation to the theories of 'gaseous' and 'liquid' molecules—'Gasonen' and 'Fluidonen' devised in recent years by de Heen, Traube, and others.

The present communication has arisen out of a correspondence on the subject with Professor van't Hoff, to whom the main idea is due.

FRIDAY, AUGUST 19.

The following Papers and Report were read:—

1. *On Crystal Structure and its Relation to Chemical Constitution. By* Professor PAUL GROTH.

The molecular hypothesis assumes that in solid bodies the molecular movements occur about certain equilibrium positions which can only be altered by the operation of external forces. In crystalline bodies the spacial arrangement of these equilibrium positions must consequently be a regular one.

The possible kinds of crystal structure—that is, the kinds of regular arrangement of congruent molecules—were first discussed by Bravais, who described fourteen such kinds of structure and distinguished them as 'space lattices.' Bravais's theory, however, only explains seven kinds of symmetry which possess the properties of crystal symmetry, and the incompleteness of his work reposes on the introduction of an unnecessary assumption, namely, that the molecules occupy parallel positions. Sohncke discarded this assumption in attacking the problem,

and merely sought for those arrangements of congruent molecules in which the arrangement of parts is the same about every molecule; he thus arrived at sixty-five regular 'point systems.' By the discovery of these, most, though not quite all, of the symmetrical relationships of the properties of crystals became explicable. Sohncke further developed his theory of crystal structure by introducing the assumption that two or more regular point systems, consisting of different kinds of molecules, may be interlaced or supposed to interpenetrate in such a way that equilibrium results. This, however, is only possible when the different point systems possess the same 'coincidence movements' (*Deckschiebungen*)—that is to say, when they are built up from space lattices of identical dimensions. This form of the theory is also deducible from the theory of regular point systems if the different individual atoms constituting the molecule are considered in place of the centres of gravity of the molecules; each set of analogous atoms then form a regular point system, and, by the interlacing of the several systems, a compound system is obtained consisting of as many component systems as there are kinds of atoms in the chemical molecule. This, the most general theory of crystal structure, may be summarised by the following definition.

A crystal—considered as indefinitely extended—consists of n interpenetrating regular-point systems, each of which is formed from similar atoms; each of these point systems is built up from a number of interpenetrating space lattices, each of the latter being formed from similar atoms occupying parallel positions. All the space lattices of the combined system are geometrically identical or are characterised by the same elementary parallelepipedon.

In this form the theory is capable of elucidating all the observed regularities of crystal structure, and it is unnecessary to assume the operation of any 'molecular forces' in addition to the forces which act upon the atoms themselves. No difficulties now arise in ascribing to the atoms the power of assuming a definite orientation, since, according to J. J. Thomson, the atoms are not mere points, but highly complex structures.

If a crystal is built up of but one kind of atom it consists of a crystalline element, and is produced from but one kind of regular-point system the properties of which depend upon the forces exercised upon each other by the similar atoms involved. In the case of a chemical compound, however, there must be just as many regular-point systems in the combined system as there are kinds of atoms in the chemical molecule, and the arrangement of the combined system must correspond with the equilibrium of the forces with which similar and dissimilar atoms act upon each other.

On solution, melting, or evaporation of the crystal the combined system separates into its component and freely moving molecules, and the relative positions in space of the point systems or space lattices, composed from the several kinds of atoms, must therefore be such as to correspond with the arrangement of the atoms in the chemical molecule. The difference between the crystalline and the amorphous state thus consists in that in the latter the chemical molecules have a mutually independent existence, whilst in the crystal the idea attached to the term molecule is different, the molecule being regarded only as a group or assemblage of atoms belonging to several interpenetrating point systems. Such an assemblage can under certain conditions be quite an arbitrary one; thus, the structure of crystalline sodium chloride—making the simplest conceivable assumption—consists of a cubic space lattice of sodium atoms and a similar space lattice of chlorine atoms, the latter atoms occupying the mean points in the lattice of sodium atoms. It is obviously a matter of quite arbitrary choice with which of the neighbouring sodium atoms a particular chlorine atom will remain combined as a molecule of sodium chloride when the molecules of the latter separate during the passage into the amorphous state by melting, solution, &c. The same considerations naturally hold when, instead of two simple space lattices, two regular-point systems consisting of chlorine and sodium atoms are imagined to coalesce. In this case any multiple of the complex $NaCl$ may be regarded as the 'molecule,' and thus has arisen the failure of all attempts hitherto made to determine the molecular magnitudes of crystalline bodies.

In order to ascertain the crystal structure of a substance with any degree of probability the most complete possible knowledge is required concerning it, such as of its optical properties, its cohesion relationships, the orientation of its different solubility directions (etch figures), and more especially the knowledge of its crystalline form under the most widely differing conditions of formation. If the product of only one crystallisation is examined, the possibility is incurred that the crystals so produced exhibit casual forms developed under quite special conditions of growth; and only by investigating many different crystallisations separated from different solvents under different conditions of temperature, &c., does it become possible to recognise those faces the development of which is most favoured during growth or, what is the same thing, to learn which planes are parallel to the greatest density of structure. If these planes are taken as the elementary faces, it is always found, not only that they are identical with the cleavage plane, with the most stable plane of twinning, &c., but also that the other forms present on the crystal assume the simplest indices. The greater the number of forms observed upon the crystals, so much the greater is the probability of being able to choose the correct elements for the crystal, because the faces most likely to be favoured during the growth of the crystal are those the indices of which are composed of the simplest numbers. Having found the correct elements of the crystal, it is a simple matter of calculation to ascertain the ratio of the three parameters and the angles of the elementary parallelepipedon upon which the structure of the crystal is built up, and which is therefore a prime characteristic of the structure.

Since the equilibrium in a crystal structure is dependent on the conditions of movement of the component atoms, the stability of the equilibrium must alter with the temperature; and since each form of structure may possess several stable equilibrium positions of different degrees of stability, it follows that a particular crystal structure will assume the most stable of the possible kinds of equilibrium only within a certain range of temperature, constant pressure being assumed. Outside these limits other kinds of arrangement will be in more stable equilibrium, and on exceeding the limits a discontinuous change of all the physical properties of the body will occur—that is to say, a change into another modification of different crystal structure will ensue. Polymorphism, the property of existing in different crystalline phases, must be distinguished from polysymmetry, or the power possessed by pseudosymmetrical crystals of forming apparently simple crystals of higher symmetry by repeated twinning. Amongst the latter the change into the form of true higher symmetry can indeed take place at a specific temperature, but the change is not accompanied by a discontinuous change in the density and the specific heat. Amongst the truly polymorphous bodies, however, even when the crystalline forms of the several modifications exhibit a certain similarity, so great a dissimilarity still exists between them in physical and crystallographical respects that the various modifications must be referred to quite different elementary parallelepipeda. A difference in the crystal structure is thus introduced, and this may arise from the regular point systems, which compose the combined system, consisting each of one or of several space lattices.

On comparing the polymorphous relationships of two different but chemically similar substances it is found that the temperature (or pressure) limits of the stability of the several modifications are not the same—thus, considering analogous chloro-, bromo-, and iodo-compounds, it is often observed that the temperatures of change for the chloro- and bromo-compounds are lower than for the iodo-compound, just as is often the case with the melting-points of such analogous substances. As a result totally different polymorphous modifications of the various members of analogous series exist at one and the same temperature.

The foregoing leads to the definite conclusion that the relationships between the crystal structures of two chemically related substances can only be recognised if their corresponding modifications are available for comparison; every chemico-crystallographical comparison of two or more substances must therefore be based upon a study of the polymorphism relationships. If the existence of corresponding modifications is established by such a study, the further complete investigation of these forms leads to the determination of the most probable values of the

dimensions of the elementary parallelepipeda of the crystal structure; by taking the planes of the elementary parallelepipedon as the basis for assigning symbols to the crystal faces, the so-called 'elements' of the crystal give immediately the angles, α, β, and γ, and the relative lengths $a : b : c$ of the sides of the elementary parallelepipedon. The elements of the two comparable substances being

$$1.\ a_1 : b_1 : c_1 \text{ and } \alpha_1, \beta_1, \gamma_1$$
$$2.\ a_2 : b_2 : c_2 \text{ and } \alpha_2, \beta_2, \gamma_2,$$

the comparison of the two sets of elements, if all the other necessary conditions are fulfilled, permits the determination of the alteration which ensues in the structure of the crystal 1, if it be converted by substitution into the substance of crystal form 2. This alteration may be regarded as a 'homogeneous deformation' of the parallelepipedon, because a homogeneous edifice—the crystal structure of form 1 becomes thereby converted into another homogeneous edifice—the crystal structure of the crystal of modification 2. The character of this deformation cannot be recognised through the comparison of the axial ratios of the two substances if these are stated in the ordinary way, but can only be ascertained if the axial ratios are expressed in terms of the same unit. For this purpose an exact determination of the specific gravity of the two substances is made and the 'equivalent volume' calculated therefrom; the dimensions (parameters) of the elementary parallelepipeda can then be at once referred to the same unit, namely, to the side of a cubic elementary parallelepipedon of a substance of which the molecular weight is equal to the density (equivalent density = 1). Such comparable parameters are termed the 'topical axial ratios,' and are described as χ, ψ, and ω. The comparison of the following substances may be quoted as a simple example.

Ammonium iodide crystallises in hexahedra and exhibits a perfect cleavage parallel to {100}, so that its crystal structure is undoubtedly hexahedral or cubic. Tetramethylammonium iodide crystallises in the tetragonal system and shows perfect cleavages parallel to {100} and {001}; its most probable crystal structure therefore differs from that of ammonium iodide only in the ratio of the axes a and c. The direction in which the crystal structure has been altered by the substitution of 4H by $4CH_3$ is seen by a comparison of the topical axial ratios; as the following table shows, the principal axis c has undergone no noteworthy change, but the parameter of the two axes a and b is much greater in the methylated compound. Tetraethylammonium iodide is similarly tetragonal and exhibits a regular increase of the parameter of the two equal axes in the same direction; the increase in the equivalent volume is also quite regular during the transition from 4H to $4CH_3$ to $4C_2H_5$. On further attempting to lengthen the dimension a and b, by exchanging $4C_2H_5$ for $4C_3H_7$, a quite different deformation comes into play. As a result of this ω and ψ increase, and χ decreases.

	NH_4I	$N(CH_3)_4I$	$N(C_2H_5)_4I$	$N(C_3H_7)_4I$
Equivalent volume	57·51	108·70	162·91	255·95
$\chi =$	3·860	5·319	6·648	6·093
$\psi =$	3·860	5·319	6·648	7·851
$\omega =$	3·860	3·842	3·686	4·933

The so-called morphotropic relationships between numerous organic substances which have been brought to light during many years past consist mainly in the observation that the substitution of H by CH_3, NO_2, OH, &c., gives rise in many cases to but partial changes in the crystalline form. In order, however, to determine the direction of deformation, as has been done above for the alkylated ammonium iodides, all the substances must be studied in accordance with the principles laid down above, and their specific gravities determined; further, in cases in which no morphotropic relationships can be traced it must be ascertained whether the substances compared are not different—non-corresponding—modifications. Regularities from which conclusions can be drawn concerning the position of the atoms or atomic groups in the crystal structure can only be traced as a result of this kind of complete investigation of long series of chemically related

compounds. That such conclusions can be drawn is evident from the above example.

The only study of related substances which satisfies all the requirements noted above is to be found in the brilliant work of Tutton on the sulphates and selenates; this relates to the comparatively small changes which result from the replacement of K by Cs, Rb and NH_4 in so-called 'isomorphous compounds.' In spite of the smallness of the changes produced, Tutton has been able to establish definite relationships between the atomic weight of the metal concerned and the crystal structure, and his work therefore stands as a sample of the way in which chemico-crystallographical investigations must in the future be carried out for the purpose of determining the mutual relationship of the crystal structure and the chemical substance.

As is well known, isomorphous substances possess the power of forming homogeneous mixtures, and, since in these mixtures the properties continuously change with the composition, they have been described as 'solid solutions.' Such a miscibility often exists, however, within certain limits between substances possessing totally different crystal structures, so that the solidification curves of the molten mixtures of such substances show just the same relationships as if the mixtures had been made from two truly isomorphous materials. It is therefore incorrect to conclude that two substances are isomorphous from an examination of the melting and solidification curves of their mixtures.

Only those substances which exhibit corresponding crystal structures as a result of their chemical analogy can be regarded as isomorphous; mixed solutions of two such substances may be caused to deposit apparently homogeneous crystals in which the atoms of one element are partially replaced by atoms of another without overthrowing the equilibrium of the crystalline structure. The preservation of the equilibrium will clearly be the more easy the less the differences between the forces determining the crystal structure in the two isomorphous substances, and the less therefore also the difference between the two crystal structures. The properties of the mixture must be immediately deducible additively from those of the components; thus, for instance, each component must preserve its individual specific gravity in the mixture, as has been shown by the careful investigations of Retgers to be the case.

Lastly, the facts which Kipping and Pope have brought to light in connection with optically active and racemic compounds can be brought into unison with the above discussion on crystal structure. The crystal structure of a racemic compound contains a regular-point system of carbon atoms, one half of which is the mirror image of the other half—the other atoms present in the compound form point systems similarly arranged and constituted—whilst the pseudoracemic substances stand to the active components in the same relation as polysymmetric substances.

The object of the author is to state clearly the point of view in accordance with which previous investigations must be developed in order that generally applicable conclusions can be deduced therefrom.

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2. *On Dynamic Isomerism.* *By* T. M. Lowry, *D.Sc.*—See Reports, p. 193.

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3. *The Constitution of Phthalein Salts.* *By* Professor Richard Meyer.

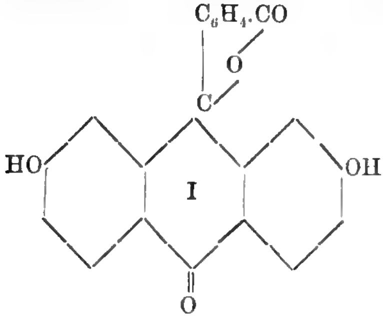
The author gave an account of his experimental work on the constitution of phthalein salts at the last Versammlung deutscher Naturforscher und Aerzte at Cassel.[1]

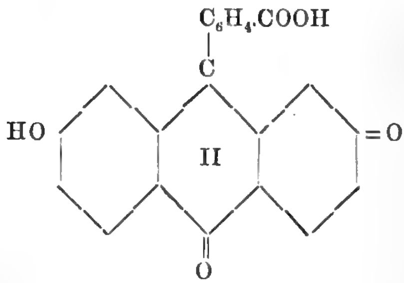
Phenolphthalein itself is colourless and is generally regarded as a lactone, whilst the quinonoid formula is assigned to its red alkali salts by the majority of

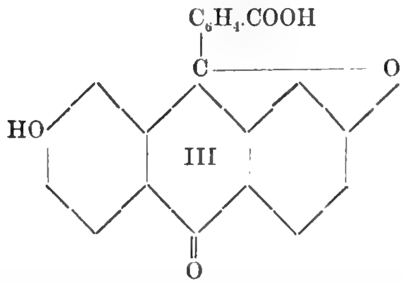
[1] *Ber. d. deutsch. Chem. Ges.*, **36**, 2949 (1903).

chemists. Fluorescein, being coloured both in the free state and in the form of salts, is regarded as being quinonoid either when free or combined.

Quinolphthalein (I), the constitution of which has been confirmed by work done in the author's laboratory, does not come into quite the same category, and its red alkali salts must be supposed to possess a meta-quinonoid constitution (II or III).







Metaquinones being at present unknown, further work on the above substances was desirable, and the author and his assistant, Mr. O. Sprengler, have therefore studied the ethers and oximes of phenol- and quinol-phthalein, preparing these substances in alkaline solution; the results of this work point to the lactonic formula of the alkali salts as being correct, both in the case of quinolphthalein and of phenolphthalein. They drew attention recently to the fact that the anilides of the phthaleins dissolve in alkali without giving rise to coloration; if these anilides have the same constitution as the phthaleins themselves, this distinction might arise from a difference in basicity. They therefore endeavoured to ascertain the equivalents of these substances. A measured volume of standard caustic-soda solution was treated for two hours at the ordinary temperature with an excess of phenolphthalein; in a second and a third experiment quinolphthalein and phenolphthalein anilide were subjected to similar treatment. The undissolved residue was filtered off and washed, the filtrate being then precipitated with dilute sulphuric acid; the precipitates were filtered, washed, dried, and weighed. The results agreed with the formulæ—

$$C_{20}H_{12}O_4Na_2,\ C_{20}H_{10}O_5Na_2,\ \text{and}\ C_{20}H_{12}O_3(NC_6H_5)Na_2.$$

Thus all three compounds behave alike as dibasic acids, and from this point of view no difference is traceable between the anilide and the free phthaleins; the anilide is, however, more feebly acidic than the phthaleins, being precipitated by the latter from its alkaline solution.

These experiments have some bearing on those described recently by A. G. Green and A. G. Perkin; but the results of these investigators differ from the present because they worked under different conditions.

The authors have made many attempts, under varied conditions, to obtain a quinonoid ether of phenol- or quinol-phthalein, employing methyl iodide and methyl sulphate both in aqueous and alcoholic solutions, and using an excess of alkali and also of sodium methoxide. In each case the same di-ethers as before

were obtained; they are colourless, and doubtless possess a lactonic constitution. Only when the neutral sodium salts of the two phthaleins are treated two new compounds are formed, in addition to the well-known di-ethers. These substances proved to be the mono-ethers, $C_{20}H_{13}O_3{\cdot}OCH_3$ and $C_{20}H_{11}O_4{\cdot}OCH_3$, and are not carboxylic but hydroxylic ethers; they could not be saponified, and on further treatment with alkyl salts yielded the lactonic ethers. They do not decompose sodium carbonate, and hence do not contain a free carboxyl group; moreover, they are colourless, and are doubtless of lactonic constitution, just as are the di-ethers. They form, however, red salts, the constitution of which is open to discussion.

The quinonoid formulæ of the phthaleins indicate the presence of one carboxyl and one phenolic hydroxyl group in the molecule, whilst, according to the lactonic formula, two phenolic hydroxyl groups are present. The etherification conditions of carboxylic acids and phenols were therefore studied, as it appeared of prime importance to ascertain whether the carboxyl group can be esterified under the conditions prevailing in the present experiments—namely, in neutral or alkaline solution. The following facts were established as the result of numerous experiments, carried out under a great variety of conditions. Phenol is always converted into its ethers by means of alkyl halogen salts and by methyl sulphate, whether the solution be alkaline or neutral, or even acid; the only point of difference is in the yield obtained. Benzoic acid, however, can only be esterified in acid or neutral solutions, but not in alkaline ones, whether alkyl halogen salts or methyl sulphate is used.

It would seem difficult to reconcile the above results with the quinonoid formula of the phthalein salts; the difficulty involved in the assumption of the quinonoid theory is also felt by A. G. Green and A. G. Perkin, and they attempt to overcome it by assuming the intermediate formation of the carbinol salt. This view would indicate that the red solution contains, in addition to the quinonoid salt, a certain proportion of carbinol salt, from which latter the lactonic ethers are produced; and that during the course of the reaction the quinonoid salt is progressively converted into carbinol salt, in accordance with the law of mass action, until the change has become complete. The carbinol salt could only be formed by opening the ring, and this could only take place whilst working in presence of excess of alkali; since, however, the author has obtained the same lactonic di-ethers in neutral solution, the opening of the lactonic ring in this case would appear to be impossible.

The advocates of the quinonoid theory point to analogies between phenolphthalein and fluorescein, but the author is of opinion that it would be very difficult to find, in one group of chemically related compounds, two substances more dissimilar than are phenolphthalein and fluorescein. Thus, for instance, R. Nietzki and P. Schroeter obtained one lactonic and three quinonoid ethers by the alkylation of fluorescein, whilst the salts of phenol- and quinol-phthalein never yielded quinonoid derivatives under the most varied conditions of working. The quinonoid ethers of tetrabromophenolphthalein, discovered by R. Nietzki and E. Burckhardt, have no bearing on this question, because they have not been prepared from the phthalein salts. It would be preferable to try to express the different behaviour of fluorescein and phenolphthalein by the aid of chemical formulæ rather than to insist on a similarity which is not warranted by the facts.

One serious difficulty arises in connection with the colour of the alkali salts: Ostwald assumes that the red colour is due to the phthalein ions, whilst the undissociated molecules are colourless. If, however, the ions are coloured, they should contain a chromophoric group, such as is present in undissociated coloured molecules; the lactonic formula does not indicate the presence in the molecule of such a chromophoric group. At the same time, it must be agreed that, however valuable the theory of chromophors has proved as a means of characterisation and classification of colouring matters, it is not sufficiently comprehensive to include all coloured organic compounds. It does not include the quinolphthaleins (and orcinphthalein), dibenzalacetone, and other colourless substances which form deeply coloured addition compounds with mineral acids. Adolf Baeyer introduced the

term 'halochromy' as descriptive of this phenomenon, and it does not seem impossible that the colour of phthalein salts is due to a kind of halochromy.

The author is continuing his work in another direction, and hopes to obtain further evidence bearing on this question.

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4. *Studies in the Dynamic Isomerism of* α- *and* β-*Crotonic Acids.* *By* R. S. Morrell *and* E. K. Hanson.

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5. *Mesoxalic Semialdehyde.* *By* Henry J. Horstman Fenton, *F.R.S.*

Mesoxalic semialdehyde (COOH—CO—CHO), it has been previously shown,[1] can be obtained by the oxidation of dihydroxymaleic acid with ferric salts at about 40°. This method is not altogether satisfactory, owing to the difficulty of removing the iron salts, and it is now found that the oxidation may advantageously be effected by means of mercuric chloride. In this case the mercury separates almost quantitatively as calomel, and any traces remaining may be removed by hydrogen sulphide. The properties of this semialdehyde are being further studied, and appear to be of considerable interest. It is evident that the aldehyde hydrate COOH—CO—$CH(OH)_2$ may be regarded as a tautomeric form of the missing trihydroxyacrylic acid, COOH—C(OH=$C(OH)_2$, and the latter should, by condensation with two molecules of urea, yield uric acid.

If a solution of mesoxalic semialdehyde is mixed with urea and heated, together with dilute hydrochloric acid, a large yield of a very sparingly soluble crystalline substance is obtained which, by its properties and composition, proves to be *glycouril*, $C_4H_6N_4O_2$. This compound was originally obtained by reduction of allantoin, and afterwards from glyoxal and urea.

It is evident, therefore, that a molecule of carbon dioxide splits off in the reaction above described; later experiments appear to indicate, however, that by modifying the conditions this loss may be prevented, in which case it is hoped that uric acid itself may be obtained.

Although the properties of glycouril have been carefully studied by various authors, the following very striking colour-reaction appears to have been overlooked: the substance is evaporated to dryness with strong nitric acid on a water bath and the white residue dissolved in caustic soda; a faint blue violet colour here results, and now, on addition of sodium hypochlorite, a very brilliant purple colour is obtained.

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6. *Note on the Influence of Radium Radiations on Atmospheric Oxidation in presence of Iron.* *By* Henry J. Horstman Fenton, *F.R.S.*

It has been pointed out by the author in previous communications[2] that the oxidation of certain hydroxy-compounds, such as tartaric acid or glycol in presence of iron, may be brought about by atmospheric oxygen in presence of sunlight, and that the products are the same as those obtained when hydrogen dioxide is employed as oxidizing agent. It is now found that the influence of radiations from radium bromide may, in certain cases, produce effects similar in this respect to those obtained by exposure to sunlight. A solution of tartaric acid, for example, containing a small quantity of ferrous tartrate, was divided into two parts and kept in the dark in presence of air, one of the tubes being placed directly over a specimen of radium bromide. On testing the solutions after a day or two with phenylhydrazine acetate a very striking difference was observed in the results, the exposed solution giving a comparatively copious precipitate of Nastvogel's osazone.

[1] Fenton and Ryffel, *Trans. Chem. Soc.*, 1902.
[2] *British Association Report*, 1895 and 1898.

7. *A Colour Reaction for Methylfurfural and its Derivatives.* *By* H. J. H. FENTON, *F.R.S.*, *and* J. P. MILLINGTON, *B.A.*

When bromo-methylfurfural is heated with dimethylaniline and a de-hydrating agent, such as phosphorus oxychloride, zinc chloride, or dry oxalic acid, an intensely blue-coloured compound is obtained. This reaction is extremely sensitive, and is given by bromo-, chloro-, iodo-, or acetoxy-methylfurfural, and by methylfurfural itself, but not by the condensation products previously described.[1] As a dye the blue colour appears to be very permanent in the dark, but slowly fades in sunlight.

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8. *A Reaction for Keto-hexoses.* *By* HENRY J. HORSTMAN FENTON, *F.R.S.*

By oxidation of lævulose, cane sugar, inulin, or sorbose in presence of ferrous iron at about 90°–100°, and heating the resulting solution with phenylhydrazine-p-sulphonic acid, a compound is obtained which dyes silk a rich brownish pink colour, which is remarkably stable and permanent. This reaction appears to be especially characteristic of keto-hexoses or substances which yield them on hydrolysis, and is given by dextrose, milk sugar, maltose or starch only to a limited extent, or not at all.

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9. *On the Energy of Water and Steam at High Temperatures.* *By* Professor C. DIETERICI.

The author has devised a method for determining the specific heat of water at temperatures up to 300° C. The water is enclosed in quartz tubes, which are sufficiently strong to withstand the pressure of steam—namely, about 100 atmospheres at 300° C.—and the determinations are made with the aid of the ice calorimeter. The results obtained may be expressed by the formula

$$c_t = 1{\cdot}0160 - 0{\cdot}0_3 6057t + 0{\cdot}0_5 4302t^2,$$

in which the specific heat, c_t, is given as a function of the temperature. The formula holds between 50° and 300° C., but does not hold below 50° C., because at such low temperatures the point of maximum specific heat first observed by Rowland occurs.

The observations made with water completely enclosed in a tube give the difference between the energy of the liquid water at t° C. and that of the water at 0° C. Since the heat of evaporation is known or calculable, this quantity, diminished by the external work, gives the energy difference between saturated steam and liquid water at t° C.

Very careful observations have been published by Sir W. Ramsay and Professor S. Young ('Phil. Trans.,' 1891) on the pressure of unsaturated steam between 140° and 270°; and since the relation between energy change and volume at constant temperature is given by the equation

$$\left(\frac{\partial U}{\partial v}\right)_\tau = \tau\left(\frac{\partial p}{\partial \tau}\right)_v - p$$

of the mechanical theory of heat, the change of energy of superheated steam depends only on the pressure, and can be calculated from the author's present observations. It is, therefore, possible to calculate the energy isothermals and to draw the isothermal lines for water.

After applying the most accurate methods of calculation possible to the new observations, the author draws the following conclusions:—

At about 200° C. the specific heat of superheated steam at constant volume is 0·5, and is practically independent of the volume if the latter is much greater

[1] Fenton and Gostling, *Trans. Chem. Soc.*, 1899, 423, and 1901, 807.

than the saturation volume. As, however, the volume diminishes to the volume of saturation, the specific heat increases to about 0·7. The specific heat at constant pressure, C_p, similarly varies from 0·6 to 0·8. Further, in the well-known equation of state of Van der Waals

$$p + \pi = \frac{RT}{v - b},$$

the cohesion pressure, π, cannot be taken as $\frac{a}{v^2}$, but is such a function of v and T that it has a considerable value for large volumes at low temperatures, and for small volumes at higher temperatures.

10. *On the Specific Heat of Gases at High Temperatures.* *By* Professor H. B. Dixon, *F.R.S.*

11. *The Oxidation of Carbohydrates by Hydrogen Peroxide in presence of Ferrous Sulphate.* *By* R. S. Morrell *and* A. E. Bellars.

12. *Report on Wave-length Tables of the Spectra of the Elements and Compounds.*—See Reports, p. 66.

MONDAY, AUGUST 22.

The following Papers were read:—

1. *Sur la photographie des spectres d'étincelle directe des minéraux sulfurés.* *Par* le Comte A. de Gramont, *D. ès Sc.Ph.*

J'ai repris, avec l'aide des procédés photographiques, des recherches que j'avais poursuivies autrefois sur les spectres des minéraux ou des produits métallurgiques bons conducteurs, entre deux fragments desquels jaillit l'étincelle d'une ou plusieurs bouteilles de Leyde alimentées par une bobine de Rhumkorff. J'avais établi ainsi[1] que l'étincelle condensée dissocie les composés en donnant des spectres de lignes très vives où chaque corps est représenté par les raies caractéristiques de son spectre individuel. Les corps conducteurs, ou seulement volatilisables dans l'étincelle, se comportent donc spectroscopiquement, comme on l'avait auparavant constaté pour les alliages métalliques, mais ils donnent en plus les spectres de lignes des *métalloïdes.* Étudiant ensuite les principaux sulfures métalliques minéraux, j'avais donné les longueurs d'onde de leurs raies, et notamment de celles qui caractérisent le *soufre* dans leurs spectres visibles. Mais les raies les plus sensibles à l'œil ne sont pas, comme on le sait depuis longtemps, celles qui impressionnent le mieux la plaque photographique. Aussi ai-je repris photographiquement la recherche du spectre du soufre dans les sulfures, en superposant sur un même cliché le spectre du minéral étudié, galène PbS, ou argyrose Ag^2S, avec celui d'un tube de Plücker chauffé, contenant du soufre en vapeurs; les raies données par le tube se trouvent ainsi sur le prolongement des raies correspondantes du sulfure minéral. Deux séries de clichés ont été prises: (1°) avec un spectrographe à partie optique toute en quartz, prisme Cornu (droit et gauche) et lentilles non achromatiques de 40 cm. de foyer; on avait ainsi tout le spectre

[1] *Comptes Rendus des Séances de l'Académie des Sciences de Paris,* 2 Juillet 1894, 8 Juillet 1895; *Bulletin de la Société Française de Minéralogie,* 1895; et vol. i. *de l'Analyse spectrale directe de Minéraux* (Librairie Béranger, Paris, 1895).

photographiable ; (2°) avec deux prismes en flint lourd et un objectif achromatique de 35 cm. de foyer ; on obtenait ainsi avec une dispersion suffisante la partie comprise entre $\lambda 500\mu\mu$ et $\lambda 350\mu\mu$. L'étincelle était fournie par une bobine de Rhumkorff donnant de 3 à 5 cm. d'étincelle, chargeant un condensateur formé de deux, trois, ou quatre jarres de Leyde dont chaque armature offrait environ 12 décimètres carrés de surface, et une capacité de 0·0043 microfarad par jarre. Les minéraux étudiés en petits fragments, comme ceux des essais au chalumeau, étaient maintenus à une distance d'un millimètre environ par des pinces à bout de platine. Il est utile de ménager, dans le circuit de décharge des jarres, une coupure à écartement variable, afin de régler le potentiel de l'étincelle sans augmenter l'écartement des minéraux dont le spectre est photographié. L'introduction d'une très faible self-induction (0^{H} 00008 Henry, environ) élimine le spectre de l'air, mais affaiblit beaucoup le spectre du soufre, qu'il est avantageux de renforcer en augmentant la condensation jusqu'à trois ou quatre jarres. Dans une étude spéciale de l'action de la self-induction sur les spectres de dissociation des composés[1] j'ai d'ailleurs étudié les conditions de disparition des spectres des métalloïdes.

Dans l'observation visuelle du spectre les groupes de raies du soufre les plus caractéristiques sont situés dans le vert : α (5665 à 5509) ; β (5473 à 5429) ; γ (5243 ; 5320) ; δ (5213 ; 5201), la raie β (5453) étant la dernière à disparaître et la plus sensible.

Il n'en est plus de même avec le procédé photographique, à cause de la limite d'impressionnabilité des plaques au gélatino-bromure. Les groupes les plus caractéristiques ont varié, et se trouvent alors dans le bleu, l'indigo et surtout dans le violet. L'emploi de systèmes optiques en flint est tout indiqué, l'absorption de cette substance pour les rayons plus réfrangibles que $\lambda 350\mu\mu$ ne présentant pas d'inconvénient dans ce cas, et sa forte dispersion permettant de résoudre plus facilement qu'avec le quartz ou le spath les groupes de raies multiples mais non très réfrangibles qui décèlent le plus nettement le soufre. Voici le tableau de ces raies photographiées avec un tube à soufre d'abord, puis avec la galène et avec l'argyrose. Je donne ici les valeurs de MM. Eder et Valenta pour les longueurs d'onde des raies. Mes déterminations concordaient avec les leurs à deux unités prises du cinquième chiffre, mais les intensités relatives des lignes dans la partie la plus réfrangible, qui ne figure pas ici, étaient notablement différentes, et je me propose de reprendre l'examen de cette question dans un travail ultérieur.

Sη	4812·0		4354·7	Sρ	4189·9	3933·6
Sθ	4716·4		4332·9		4174·5	
Sμ	4552·6	Sπ	4294·6		4162·9	3919·5
	4525·1		4285·1		4153·3	
	4483·5		4267·2		4145·3	3497·4
	4461·2		4253·8		4142·4	
	4362·6					

Toutes ces raies sont d'intensité notable. Les groupes les plus caractéristiques et les plus sensibles sont Sπ et surtout Sρ.

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2. *Quelques observations sur le groupement des raies du spectre du silicium d'après l'effet de la self-induction, et sur leur présence dans les spectres stellaires.* *Par* le Comte A. de Gramont, *D. ès Sc.Ph.*

Dans une courte note[2] présentée l'an dernier au meeting de la British Association, à Southport, j'ai donné les premiers résultats de mes recherches sur la comparaison entre les raies du spectre d'étincelle du silicium qui résistent ou disparaissent sous l'action de la self-induction, et les raies correspondantes des spectres stellaires.

[1] *Comptes Rendus de l'Académie des Sciences de Paris*, 5 et 26 Mai 1902.

[2] 'Sur le spectre de self-induction du silicium et ses comparaisons astronomiques,' rectifier la faute d'impression suivante : dans le doublet δ lire *5979* au lieu de 5879. D'autre part de nouvelles mesures photographiques m'ont permis de donner des mesures plus précises du doublet γ.

J'ai repris récemment ce travail avec un prisme composé de Rutherford et un objectif de 45 cm. de foyer, et je voudrais ajouter ici les résultats que j'ai obtenus et comparés avec le groupement des raies du silicium tel que Sir Norman Lockyer le fait d'après des températures supposées croissantes de I. à IV.[1]

Lockyer. Groupes thermiques.		A. de Gramont. Classification basée sur l'effet de la self-induction.			
IV.	4089·1		4089·3	O ?	Disparaissant avec le spectre de l'air et sous l'action d'une très faible self-induction. $0^{H}\cdot00009$.
	4096·9		4097·3	A_2 ?	
	4116·4		4116·5	A_2 ?	
			4103·5	A_2 ?	
III.	4552·8	Si δ	4552·3		Très affaiblies avec la self précédente, disparaissent pour une self-induction de $0_{H}\cdot00060$.
	4568·0		4567·5		
	4574·9		4574·6		
		Si η	3807·5		
			3796·0		
			3791·5		
II.	3853·9	Si ζ_2	3854·2		Les dernières à disparaître pour une self-induction voisine de $0^{H}\cdot00620$.
	3856·1		3856·2		
	3862·7		3862·7		
	4128·1	Si ϵ	4128·2		
	4131·1		4131·0		
	5042·0				
	5057·0				
I.	3905·8	Si ζ_1	3905·7		Résistent à une self-induction de près de $0^{H}\cdot03000$ sans être affaiblies.
	4103·2				
		Si γ	5044·0		
			5058·7		

Les lignes du groupe IV., qui d'après Sir Norman Lockyer indiqueraient une température excessive, ont toujours, sur mes clichés, accompagné les raies de l'air et disparu avec elles. Elles coïncident avec des lignes de l'oxygène ou de l'azote, mesurées par Neovius, Exner et Kaschek, ou Hemsalech. Ces deux gaz ont d'ailleurs été reconnus dans plusieurs étoiles d'Orion et dans β Crucis,[2] où l'on rencontre aussi les raies du silicium. Je crois donc que les raies du groupe IV. pourraient appartenir à l'air, de même que la raie 4103·5 du groupe I., qui serait différente de 4103·10 signalée par Rowland dans le spectre solaire et dans le spectre d'arc du silicium.

Le groupe III. devrait comprendre le triplet Siη qui accompagne Siδ dans ϵ Canis Majoris et dans plusieurs étoiles d'Orion, et qui disparaît dans les mêmes conditions.

Il faudrait, au contraire, retirer du groupe II. le doublet vert Siγ qui résiste absolûment à la plus forte self-induction dont j'aie disposé—ce sont des raies de basse température, et elles devraient être rangées dans le groupe I. avec la ligne Siζ_1 (3905·7), commune à l'arc et à l'étincelle, et qui se voit dans le spectre solaire.

Pour les longueurs d'ondes des lignes des spectres d'étoiles que j'ai identifiées avec celles du silicium, je m'en suis rapporté aux nombres donnés dans les publications de MacClean, de Lockyer, de J. Lunt,[3] et surtout de Miss Maury: 'Spectra of Bright Stars.'[4] Ce dernier mémoire contient une table des 'Orion lines' trouvées dans les groupes I.–VII. de sa classification stellaire; parmi les raies qui y figurent j'ai trouvé, en sus des raies de l'hydrogène et de l'hélium, la plupart des raies du silicium que je viens de donner ci-dessus, et notamment Siδ, Siϵ, Siζ_2, Siη (3791). On y voit aussi celles du groupe de raies IV. de Lockyer, que je suppose dues à l'azote et à l'oxygène.

[1] *Proc. of the Roy. Soc.*, vol. lxvii. 1901, p. 403.
[2] MacClean, *Spectra of Southern Stars*, London, 1898; and *Comparative Stellar Spectra*, Phil. Trans. 1898.
[3] *Roy. Soc. Proc.* 1901, vol. lxvii. p. 403.
[4] *Ann of the Astr. Obs. of Harvard College*, vol. xxviii.

En comparant les raies du silicium avec leurs correspondants dans les spectres stellaires, et en observant la répartition de celles-ci suivant les grandes classes d'étoiles des quatre types de Secchi, nous obtiendrons les conclusions suivantes :

1°. Seules les étoiles de la première classe (à hydrogène et à hélium) montrent les raies du silicium que supprime la self-induction. Les étoiles à hélium, par exemple celles d'Orion ou ϵ Canis Majoris, réputées les plus chaudes, donnent avec intensité les raies qui disparaissent les premières: Siδ, Siη. Au contraire, les étoiles à hydrogène, comme Sirius, et celles qui se rapprochent du type solaire, comme Procyon, donnent surtout Siϵ, Siζ_2, qui disparaissent les dernières par l'accroissement de la self. Deneb (a Cygni), qui paraît être à un stage intermédiaire, montre simultanément ces différentes raies propres à chacune des deux catégories d'étoiles.

2°. Les étoiles de la seconde classe, du type solaire, montrent les raies spéciales à l'arc, y compris ζ_1 qui résiste à la self, et se voit aussi dans le 'flash spectrum' des éclipses. Il serait intéressant de rechercher si quelques-unes des étoiles de cette classe ne donnent pas aussi les doublets persistants, Sia et Siγ.

3°. Les étoiles des troisième et quatrième classes, à spectres de bandes et réputées de température peu élevée, n'ont pas montré de raies du silicium.

En admettant, donc, ce qui est de toute vraisemblance, que l'action de la self-induction fait disparaître les raies de haute température, en laissant subsister seulement celles de l'auréole de l'étincelle, on voit que la répartition des raies du silicium dans les étoiles vient confirmer les classifications basées sur les températures relatives attribuées à celles-ci.

3. *Changes produced by the β-rays.* *By* Sir WILLIAM RAMSAY, *K.C.B.*, *F.R.S.*

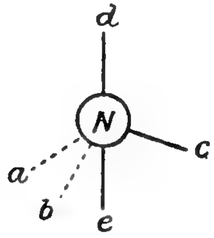
4. *The Stereochemistry of Nitrogen.* *By* H. O. JONES, *M.A.*, *D.Sc.*

See Reports, p. 169.

5. *On the Pentavalent Nitrogen Atom.* *By* Professor OSSIAN ASCHAN.

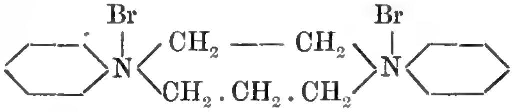
The author has previously ('Zeits. f. physik. Chem.,' 46, 1903, 293) expressed the view, which is in accordance with that of van't Hoff ('Die Lagerung der Atome im Raume,' 2te Aufl., 1894, 136), that the valency directions of the pentavalent nitrogen atom are arranged as in the appended figure:—

FIG. 1.



By the addition of trimethylene bromide, $CH_2Br.CH_2.CH_2Br$, to ethylenedipiperidide, $C_5H_{10}N.CH_2.CH_2.NC_5H_{10}$, and of ethylene bromide to trime-

thylenedipiperidide, $C_5H_{10}N \,.\, CH_2 \,.\, CH_2 \,.\, CH_2 \,.\, NC_5H_{10}$, the author has obtained two stereoisomeric compounds having the constitution,



which he was unable to resolve into optically active components by the aid of Pope's method with d-camphorsulphonic acid. Both compounds would therefore seem to possess symmetrical configurations, and this is only possible if the above conception of the arrangement of the valency directions of the pentavalent nitrogen atom is correct.

Since the attempts at resolution were carried out in aqueous solution and as possibly the d-camphorsulphonic acid is not capable of effecting an easy separation of the stereoisomerides, the two ethylenetrimethylenedipiperidide dibromides were caused to react with silver d-bromocamphorsulphonate in absolute methyl alcoholic solution. Both gave highly crystalline ethylenetrimethylenedipiperidide d-bromocamphorsulphonates which were separated by crystallisation into four and three fractions respectively, the fractions being then converted into the difficultly soluble iodide by precipitation with potassium iodide. The samples of iodide from the first and last fractions were then immediately examined polarimetrically, but were found to be optically inactive.

The author finds in these results a confirmation of his previously expressed views on the configuration of ammonium compounds, and notes also that this view possesses the greatest probability on grounds of a mechanico-chemical nature.

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6. *The Asymmetric Nitrogen Atom. By* Professor E. Wedekind.

In 1899 I succeeded in preparing isomeric series of salts of phenylmethylallylbenzylammoniumhydroxide by different methods; since then many attempts have been made to find analogous cases of isomerism among other asymmetric ammonium salts, and so to explain the nature of this peculiar phenomenon. I have already published the results of numerous experiments made with cyclic quaternary salts of tetrahydroquinoline and isoquinoline, and with methylethylphenylallylammoniumhydroxide, and now describe the results of experiments carried out with the toluidines, to see if these bases behave like aniline.

The asymmetric salts of *para*-toluidine can be made by three methods. In spite of analogous constitution, they behave very differently from the corresponding compounds in the aniline series. Firstly, the iodides

$$(CH_3.C_6H_4)\,(C_2H_5)\,(C_3H_5)\,(CH_3)\,N.I.$$

prepared by three different methods, were at once obtained crystalline, and showed chemical and crystallographical identity. The iodide and bromide are not isomorphous; the crystals of the former are rhombic, of the latter monoclinic. Still more remarkable was the difference in the case of the homologous benzyl salt $(C_6H_4 \cdot CH_3)\,(C_7H_7)\,(C_3H_5)\,(CH_3)$ N.I. Identical salts were obtained by all three methods. On the other hand, there is here a case of dimorphism; the crystals are triclinic, but show different angles. One form crystallises from alcohol, the other from water. The iodide and bromide, however, are not isomorphous; and the crystals of the latter show hemihedral faces. Different relations were observed in the *ortho*-toluidine series. The tertiary bases showed but little tendency to combine with the alkyliodides (this is due to the sterochemical hindrance of the methyl group in the ortho-position). The salts obtained with benzyl and allyliodide were amorphous. By the use of methyl iodide crystals were obtained; the quantity, however, was too small to allow of chemical and crystallographical examination. The properties of the latter salt seem to show that there is here a second case of the new nitrogen isomerism.

Since the preparation of optically active nitrogen compounds the question has

remained undecided whether every difference in the groups attached to the nitrogen atom was sufficient to cause activity. Contrary to expectation, I have been unable to obtain optically active forms of the asymmetric salts of the above-mentioned paratoluidine series. The failure was probably due to unfavourable solubility conditions, and also to a tendency to autoracemisation. The latter phenomenon was observed by Pope and by myself in the case of the active α-phenylmethylallylbenzylammonium iodide.

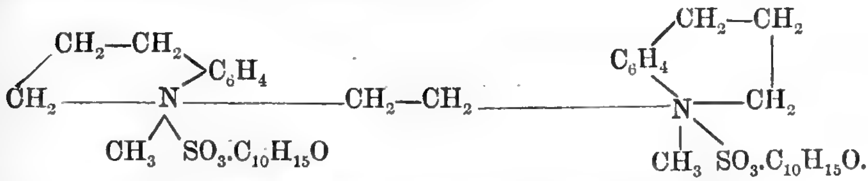
This phenomenon was formerly explained by assuming the dissociation of the salt into benzyl iodide and allylmethylaniline, according to the equation :—

$$(C_6H_5)\ (C_3H_5)\ (CH_3)N\ (C_7H_7)I \rightleftarrows C_6H_5\ (C_3H_5)\ (CH_3)N + C_7H_7\ I.$$

That is to say, by the easy passage, under certain conditions, of pentavalent into bivalent nitrogen, and the consequent destruction of space asymmetry, and, therefore, also of optical activity. As a matter of fact, the iodide is largely dissociated in boiling chloroform solution. Whether this is also the case in chloroform solution at *ordinary* temperature could not then be decided. H. O. Jones, however, by using Barger's microscopic method for determining molecular weights, was able to show that such salts possess normal molecular weights in chloroform solution at ordinary temperature. The explanation of the mechanism of autoracemisation in the case of the active asymmetric ammonium salts becomes, therefore, as difficult as that of the spontaneous racemisation of the active esters of brom-fatty acids, unless it is assumed that the degree of dissociation at any instant is at ordinary temperatures so small as to escape measurement by the methods employed. This small amount of dissociated material would on recombination form the racemic salt. In the next instant another small quantity of the active salt would be dissociated and racemised, and so on until the whole mass was racemised. It is evident that, in spite of this process, an approximately normal molecular weight might be found. The velocity of the change—that is to say, the amount of active salt dissociated in the unit of time—depends upon the strength and duration of the light falling on the solution, and also on the temperature. I am at present engaged in the measurement of the velocity of autoracemisation under various conditions, in the hope of elucidating this problem.

The important question whether all asymmetric ammonium salts, independent of difference in groups, could be obtained in active forms has at last been answered. Jones, after failing to obtain ammonium salts of the type N.a.a.b.c.X., and also cyclic salts in active forms, succeeded in resolving the phenylethylmethylbenzylammonium base at almost the same time. I prepared the iodide and the dextro-camphorsulphonate of the same base, and succeeded in resolving the latter by a *single* recrystallisation from methyl formate ($[M]_D$ of the dextro-phenylbenzylethylmethyl d-camphorsulphonate = + 69°). By employing the same useful solvent I have also recently been able to resolve the homologous propylphenylbenzylmethylammoniumhydroxide. The d-camphorsulphonate of the dextro base forms transparent rhombohedra, which attain a diameter of one or more centimetres. The highest rotatory power hitherto observed is $[M]_D = +62°$. The iodide prepared from the camphorsulphonate was *active*. Activity did not result when acetone or acetic ether was employed. I am at present working on the resolution of the homologous isobutyl base.

The problem of resolving salts containing two asymmetric nitrogen atoms appeared particularly interesting.[1] For this purpose I have converted ethylene dikairolinium iodide[2] into the di-dextro-camphorsulphonate.

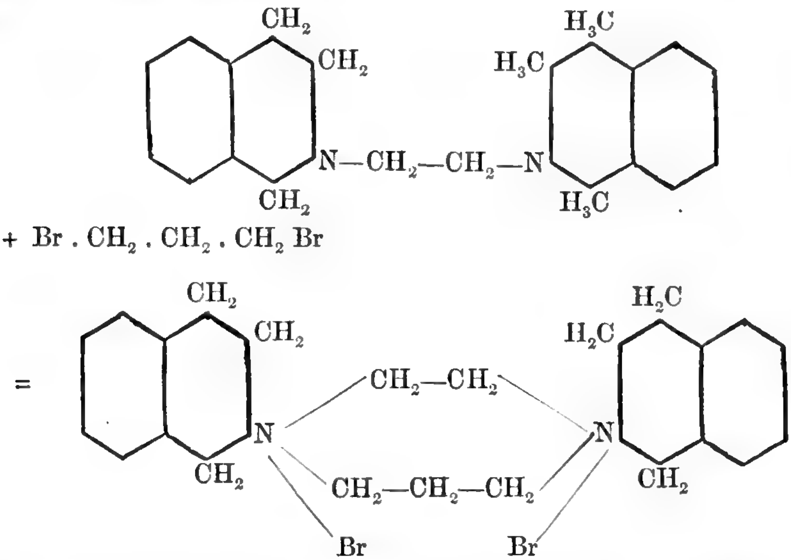


[1] O. Aschan, *Zeitschr. f. physikal. Chemie*, **16**, 312 *ff*.
[2] E. Wedekind, *Ber. d. deutsch. Chem. Ges.* **36**, 3796.

The single fractions showed the *same* specific rotatory power and a molecular rotation of + 103° to 104°. The di-*d*-brom-camphorsulphonate crystallises remarkably well, and seems to offer a better chance of resolution. The acetic ester of kairolinium d-camphorsulphonate ($[a]^D = 11{\cdot}7°$) has not been obtained in active forms either by Jones or myself.

The problem of examining the so-called inactive isomers of asymmetric nitrogen offers great difficulties. Anyone who has examined so great a series of asymmetric systems for isomers without success as I have, will understand me when I call the single case of isomerism in the series of benzylallylphenylmethylammonium salts (which I discovered several years ago) 'remarkable,' and to a certain extent a 'puzzle.' Kipping and Aschan have both taken exception to this expression. I think, however, that everyone will agree with me that the extraordinary rarity of such isomers—predicted by most theories—is most striking, especially as in the observed case the isomers possess about equal stability. Since then I have found a new case in the series of asymmetric *ortho*-tolyl-ammonium salts, but on account of experimental difficulties I have not been able to establish it with absolute certainty. Since among the homologues of the asymmetric aniline salt, with this exception, no isomers have been found, I have commenced experimenting with the asymmetric phenetidine and anisidine bases.[1] Paraphenetylbenzylallylmethylammonium iodide (and the corresponding d-camphorsulphonate) are beautifully crystallised salts when made by the combination of allyl or benzyl iodide with the corresponding tertiary bases. The third method—addition of methyl iodide to benzylallyl-p-phenetidine—leads to an amorphous salt. Experiments are already in progress to prove if this is really a case of isomerism.

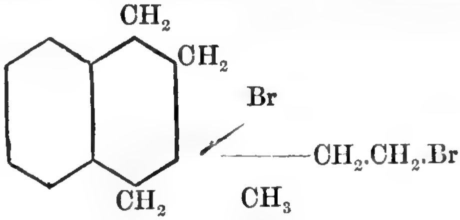
O. Aschan has recently discovered a new case of isomerism in the series of the diacid ammonium salts which differ in solubility. At the time of his publication I was working on the ethylene bases of the tetrahydro*iso*quinoline series. I therefore tried whether the above-named bases, which in contradistinction to the piperidine derivatives are quite unsymmetrical, possess analogous powers of reaction. The reaction between trimethylene bromide and ethylene di-tetrahydroisoquinolide takes place almost quantitatively at 100° C. The equation probably is:—



According to this, the salt, which is rather easily soluble in water, would contain a seven-atom heterocyclic system. The prospects of successfully preparing this system by the second method are not good, since, according to my experience,

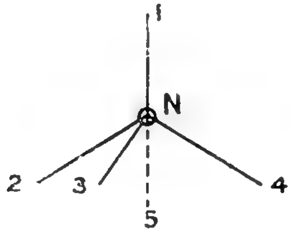
[1] I intend to try to resolve the fatty asymmetric base of Le Bel, $N(CH_3)(C_2H_5)$ $C_3H_7)(i.C_4H_9)OH$ by the new method.

ethylene bromide seldom reacts with tertiary bases in the normal manner. Isokairolin itself with ethylene bromide gives almost exclusively the salt:—



It has not yet been found possible to bring the Br in the —CH_2Br group into reaction with a second molecule of isokairolin.

I do not consider that our present knowledge is sufficient for successful theoretical speculation on the configuration and isomerism relations of the pentavalent nitrogen atom. This, however, is certain, viz.: in active ammonium salts the tetra-atomic radical N. a. b. c. d., the centre of activity, must possess *tetrahedric* grouping. This radical occurs in solution as the free active cation. The fifth valency, which is not always satisfied, cannot—apart from other grounds—possess equal value. I picture it in a rectilinear lengthening of a tetraheder axis, as the following sketch shows:—



This configuration is that proposed long ago by van't Hoff, and since then revived by Aschan. The latter has also deduced the inactive isomers (prepared by Le Bel, Kipping, Aschan, and Wedekind) from this scheme. In my opinion, the change of places of the different radicals, or, still more, the lack of change of places of the different radicals (appearance of isomerism), is so little understandable that even with the help of this model we cannot as yet form any clear ideas of the intramolecular reactions among the ammonium salts. I incline more and more to the opinion that, in the case of nitrogen which shows such different behaviour, one must discard the idea of a fixed valency. The theories which Werner has developed for carbon may be useful here. They allow, too, of an explanation of autoracemisation without the assumption of dissociation. Let us consider affinity as a force acting uniformly from the nitrogen atom, considered as a sphere, towards the surface. Then we can imagine the five radicals fixed as five 'valency positions' on the surface of the sphere. Four of these could take up a tetrahedral grouping, if in this position the greatest exchange of affinity took place. Now, the intra-molecular movements of the radicals in substituted ammonium salts are particularly evident. This is proved by the tendency towards change of place. These movements appear, then, as pendulum-like oscillations about the valency position, and are increased by rise of temperature, by the action of sunlight, and by other unknown causes, until, finally, a change of place occurs, just as Werner assumes in the case of compounds containing asymmetric carbon. (Explanation of autoracemisation of brom-succinic acid.)

I do not consider it, however, impossible that the five radicals would cause a different grouping of the valency positions, when the force acting between them is of a different nature. Such groupings are perhaps the pyramid formula, or the double tetrahedron of Willgerodt. The latter might occur when two negative radicals are combined with a tertiary amine. The attractions and repulsions

between the radicals would now be quite different from those in the normal ammonium type. The configuration set forth by the double tetrahedron is the labile one, and a tendency therefore exists for it to go over into the stable ammonium form (tetrahedron or pyramid), one of the negative radicals being replaced by hydrogen or alkyl.

I think that such pictures are useful in helping us to understand the easy change of position of the radicals in quaternary ammonium salts. Further, the complex behaviour of pentavalent nitrogen becomes thereby more easily explicable.

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7. *On the Products obtained by the Action of Tertiary Bases on some Acid Chlorides. By* Professor E. WEDEKIND.

The author has previously shown ('Annalen,' 318, 99; 323, 257) that, in spite of the violent reaction which occurs between the chlorides of powerful acids and strong tertiary bases, no quaternary salt of the type

$$R_3N\begin{matrix}\diagup CO.R \\ \diagdown Cl\end{matrix}$$

is produced, but that the hydrochloride of the tertiary amine,

$$R_3N\begin{matrix}\diagup H \\ \diagdown Cl\end{matrix}$$

is obtained in quantitative yield. This fact is in so far of importance in connection with the stereochemistry of nitrogen as it indicates the reluctance of the trivalent nitrogen atom to take up two acidic or negative groups; the trivalent nitrogen atom exhibits a kind of striving to assume the most stable condition, that, namely, of which ammonium chloride is the type.

The question at once arises, in connection with the above reaction, as to what becomes of the residue of the acid chloride molecule; the solution of this problem presented extraordinary experimental difficulties, but its study has led to the discovery of several interesting facts, which may here be briefly mentioned. The author has already shown that by the action of acetyl chloride on triethylamine, pyridine, &c., dehydracetic acid is produced ('Annalen,' 323, 247); in this reaction four molecules of each component take part, in accordance with the equation

$$4CH_3.COCl + 4N(C_2H_5)_3 = 4N(C_2H_5)_3HCl + C_8H_8O_4(4C_2H_2O);$$

but when the acetic chloride is replaced by propionyl, phenylacetic or hydrocinnamic chloride, products are obtained which have only three times the molecular weight of the hypothetical substance which must be supposed to be first formed by the splitting off of hydrogen chloride from the *one* molecule of the acid chloride. Thus the condensation product from propionic chloride, $CH_3.CH_2.CO.Cl$, has the empirical formula $C_9H_{12}O_3$ or $3(C_3H_4O)$, and that from phenylacetic chloride, $C_6H_5.CH_2.CO.Cl$, corresponds to the formula $C_{24}H_{18}O_3$ or $3(C_8H_6O)$.

The latter substance proved to be fairly easily obtainable, and the first supposition that it might be a phloroglucinol derivative—the symmetrical triphenylphloroglucinol—was found untenable, because the material can under no conditions be reduced to triphenylbenzene, and is relatively very stable even in alkaline solutions.[1] The new compound shows simultaneously the behaviour of a lactone, a monoketone, and a primary alcohol; thus it gives with soda a monosodioderivative, with hydroxylamine a monoxime, with acetic chloride a monoacetyl compound, and with benzoyl chloride a monobenzoyl derivative. On treating it with ammonia under pressure it yields a very stable pyridine derivative, and this reaction shows it to be a simple homologue of pyronone (the previously known pyronone compounds contain, like dehydracetic acid, a carboxyl group in the side chain).

[1] On heating with alkalies it yields analogous products of hydrolysis to the symmetrical trialkylphloroglucinols.

The mechanism of the reaction by which the substance is formed (compare J. N. Collie, 'Trans. Chem. Soc.,' 77, 971) would seem to be that three molecules of the acid chloride first condense with evolution of two molecules of hydrogen chloride, yielding the chloride of an $\alpha\gamma$-diketonic acid in accordance with the following scheme:

$$\begin{array}{c}C_6H_5.CH_2.COCl + C_6H_5.CH_2.CO.Cl + C_6H_5.CH_2.COCl \rightarrow \\ \begin{array}{ccccc}C_6H_5.CH_2.CO. & CH & .CO. & CH & .CO.Cl \\ & \vert & & \vert & \\ & C_6H_5 & & C_6H_5 & \end{array}\end{array}$$

This hypothetical chloride then undergoes total or partial conversion into an enolic form, from which, by subsequent loss of hydrogen chloride, in which the hydroxyl group is involved, the closed pyronone ring is formed:

$$\begin{array}{cccccccccccc} & & C_6H_5 & & C_6H_5 & & & & C_6H_5 & & C_6H_5 \\ & & \vert & & \vert & & & & \vert & & \vert \\ \rightarrow C_6H_5.CH_2.C & = & C & -CO- & CH & \rightarrow C_6H_5.CH_2.C & = & & C & -CO- & CH \\ \vert & & & & \vert & \vert & & & & & \vert \\ OH & & & & ClCO & O & & & \text{———————} & & CO \end{array}$$

Since this pyronone derivative differs from those previously studied, in that it gives an oxime as well as a monobenzoyl derivative, it must be regarded as tautomeric in that it can assume the above ketonic form as well as the following enolic or hydroxylactonic constitution:

$$\begin{array}{ccccc} & & OH & & \\ & & \vert & & \\ C_6H_5-C & - & C & = & C \cdot C_6H_5 \\ \Vert & & & & \vert \\ C_6H_5.CH_2-C & - & O & - & CO \end{array}$$

The latter formula naturally gives rise to the acidic derivatives. The remarkable power which the carbonyl group in the closed ring possesses of reacting with hydroxylamine must be attributed to the multiplication of unsaturated groups in the molecule—namely, to the presence of two phenyl groups and two double bonds in the closed chain.

As was to be expected from the known behaviour of pyrone or pyronone compounds, the action of ammonia gives benzyldiphenyldihydroxypyridine:

$$\begin{array}{ccccc} & & OH & & \\ & & \vert & & \\ C_6H_5.C & - & C & = & C.C_6H_5 \\ \Vert & & & & \vert \\ C_6H_5.CH_2.C & - & N & = & C.OH \end{array}$$

Lastly, it may be mentioned that the author has made a remarkable observation upon the interaction of isobutyric chloride with tertiary amines; in this reaction an extremely volatile substance crystallising in colourless needles and having an odour of menthol and camphor is obtained. This product is formed by the condensation of only two molecules of the acid chloride, and is not a pyronone derivative but a diketone; it is in all probability a tetramethylene derivative, from which the author hopes to prepare the parent hydrocarbon.

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8. *Sur les Manganates et les Permanganates.* *Par* Dr. A. Etard.

Le permanganate de potassium est parfaitement connu, mais le manganate vert est, je crois, considéré comme une masse fondue très riche en potasse. Cependant, Mitscherlich a décrit et mesuré des cristaux de MnO^4K^2. Il ne semble pas qu'on les ait préparés depuis. Mon but n'est pas de signaler ce sel, connu autrefois, mais de décrire ses relations avec le permanganate. Quand du permanganate cristallisé

est dissous et chauffé avec un fort excès de potasse concentrée, il arrive un moment où la coloration rouge passe au vert ; en même temps il se dégage de l'oxygène très abondamment et il se dépose des cristaux verts de MnO^4K^2 qu'on a le temps de laver avec de la potasse froide, de l'alcool absolu et de l'éther.

Ces cristaux verts, dissous dans l'eau et traités par un courant d'air, absorbent l'oxygène à froid ; la liqueur devient rouge et il se dépose des cristaux de permanganate MnO^4K. Les deux réactions successives s'écrivent donc :

$$(1)\ 2MnO^4K + 2KOH = 2MnO^4K^2 + H^2O + O$$
$$(2)\ 2MnO^4K^2 + H^2O + O = 2MnO^4K + 2KOH.$$

Ce sont ces deux formules qui me paraissent nouvelles, sauf erreur. Elles expliquent les apparences souvent controversées du caméléon minéral. L'oxygène qui est dans l'eau aërée oxyde le manganate vert. Il n'y a ni équilibre chimique spécial ni influence de l'acide carbonique ni dépôt de bioxyde de manganèse.

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9. *On the Bearing of the Colour Phenomena presented by Radium Compounds.* By WILLIAM ACKROYD.

Madame Curie early observed that radium salts are white like barium salts when first prepared, but that they gradually become coloured.[1] I have associated this colour-change with the reception of external radiant energy and the consequent increase of radio-activity.[2] What I take to be confirmation of this view has been obtained in following the history of a radium bromide tube. The salt was nearly white when purchased, and in a month or two it became tawny-yellow or orange; its powers of absorption had visibly increased, and its power of exciting fluorescence in barium platino-cyanide was concurrently quadrupled. These facts may be thus diagrammatically represented :—

Colour-change and increase of absorption.
→
White, yellow, orange, tawny-orange.
→
Increase of radio-activity.

This readiness on the part of radium compounds to become coloured under the influence of external radiations may be regarded as an effort to conform to the constitutive-colour law ;[3] moreover, it is highly probable that the colour-change is effected by a minimum expenditure of energy, as in the case of other end members of vertical groups of the periodic classification of the elements. This tendency I have experimentally demonstrated in the case of chlorides of alkali metals.[4]

But while we may regard this colour-change as being slowly effected by external radiations, the comparatively sudden application of sensible heat has a very different effect. In July 1903 I strongly heated tawny-orange radium bromide, expecting to see it change in this order—red, brown, black-like mercuric oxide and other colour-changing bodies. Instead, the seething substance reverted at once to white. The colour behaviour of the radium bromide when heated is evidently anomalous like that of some other compounds of extreme members of vertical periodic groups; as, for example, mercuric iodide. Its powers of absorption are visibly lessened, and, as is now well known, the radio-active properties of the residue are also lessened. The increase in the radio-activity of the expelled emanation is another phenomenon, and probably the joint produce of radium rays and heat. Analogous effects are produced by radium rays and heat on halides of

[1] *Thesis on Radio-active Substances*, p. 30. London : *Chem. News* Office.
[2] *Lancet*, Nov. 21, 1903, p. 1464.
[3] *B.A. Report*, 1903, and *Chem. News*, 1903, **88**, 217.
[4] *Journ. Chem. Soc.*, 1904, **85**, 815.

the alkali metals.[1] Cæsium chloride was exposed to radium rays for half an hour at 16° C.; the radium compound was then removed and the temperature of the cæsium salt was raised to 37° C. The phosphorescence was now markedly increased by the rise of temperature. May we not, then, suppose that the bodies occluded in radium compounds have radio-activity conferred on them while there, and that this radio-activity is increased by the heat which is necessary for their expulsion?

Crucial tests of the validity of this energy-transformation theory appear to be presented in the following additional facts. If water be admitted to the contents of a radium bromide tube its phosphorescence is practically undiminished.[2] Rutherford has studied the matter quantitatively, and finds that solution of a solid radium compound to a thousand times its volume does not appreciably affect its radio-activity, which he has attempted to explain on the atomic disintegration theory.[3] I have, however, pointed out that under such conditions there is approximate constancy of absorption of external radiant energy which ought to result in a like constancy of radio-activity.[4]

Again, the 60 per cent. difference of heat emission in the Curie-Laborde and Curie-Dewar estimations appears to receive a rational explanation from this point of view. At normal temperature the output of heat from a radium compound was found to be of the order of 100 calories per gram of radium per hour, while at the temperature of boiling oxygen it was only 38 calories. Now a colour-changing substance, whilst passing from normal temperature towards the region of absolute zero, becomes white, or, in other words, lessens its capability of absorbing external radiant energy; and it is now suggested that probably to this cause is to be attributed the low numbers obtained by Professors Curie and Sir J. Dewar at the temperature of boiling oxygen.

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10. *Pseudomorphosis in Organic Persulphates.* *By* Professor R. Wolffenstein.

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11. *A New Theory of the Periodic Law.* *By* Professor G. J. Stokes, *M.A.*

Many mathematical and physical interpretations of the Periodic Law have been suggested. That of the author, based on a logical analysis due to De Morgan, offers itself as more than an illustration—as a method by which chemical facts may be deductively re-discovered.

It has been shown by De Morgan that between any two things x and y there are only a definite number of logical relations possible. If we take the diagrams by which these are represented and arrange the elements under them, it is shown that a number of qualitative facts in chemistry may be deductively arrived at.

TUESDAY, AUGUST 23.

The following Papers were read:—

1. *On the Velocity of Osmosis and on Solubility: a Contribution to the Theory of Narcosis.* *By* Professor I. Traube.

Upon the results of a series of investigations, by plasmolytic methods, of the velocity of the osmosis of chemical compounds into the protoplast, Overton bases the theory that the magnitude of the distribution coefficient between such substances as fat, cholesterins, and lecithins on the one hand, and water on the other,

[1] *Journ. Chem. Soc.* 1904, **85**, 816.
[2] *Chem. News*, 1903, **88**, 206.
[3] *Nature*, 1904, **69**, 222.
[4] *Ibid.*, 1904, **69**, 295.

determines the velocity of the osmosis. He assumes that in the first instance a dissolution takes place in the fatty substance of the membrane at a velocity proportional to this coefficient, and that thereupon the substance passes on from the membrane to the interior of the cell. Moreover, Overton, and independently Hans Meyer, point out that all the reliable narcotics, anaesthetics, and antipyretics belong to the class of rapidly diffusing substances, and hence they deduce the theory that the efficacy of a narcotic depends principally on its lipoid solubility. These theories, however, in so far as they concern osmotic velocity, are erroneous. The author's investigations on the constants of capillarity of substances, especially solutions, have led to the result that the greater the osmotic velocity of a substance soluble in water, the more this substance reduces the constant of capillarity of water, whilst substances which cannot penetrate membranes (with regard to which the membranes are semipermeable) raise this constant. Among hundreds of compounds examined plasmolytically by Overton, and as to capillarity by the author, there is not one case in which capillary and osmotic phenomena do not correspond. It is evident that osmotic velocity and surface tension run parallel. Hence the difference of the surface tensions—or of the internal pressures—is the motive force in osmotic phenomena; it is to this difference that osmotic pressure is due.

The theory here stated leads to a new conception of the phenomena of diffusion and solution. Suppose that an aqueous solution of a salt is brought into contact with pure water. According to the prevalent theory the salt particles or the ions, in virtue of their 'osmotic pressure,' migrate into the pure solvent, but according to the author's view it is the pure solvent which, in virtue of its low surface tension, migrates into the salt solution. Again, let two liquids capable of dissolving in each other be brought in contact, or let a solid be in contact with a pure solvent, then the solution tension will depend chiefly on the difference between the surface tensions. From this we may expect that when a liquid or solid substance dissolves in a solvent the surface tension of the solution will never fall below that of the dissolving substance, and if the surface tensions of solution and dissolving substance be equal, the solution will be saturated. The surface tension of a saturated solution is *in maximo* as low as that of the dissolved substance, consequently the latter value determines the shape of the curve of the surface tension of solutions.

From the author's former investigations he deduced the law that equal equivalents of substances belonging to homologous series, which exercise a strong influence on capillarity (ordinary alcohols, fatty acids, esters, &c.), lower the capillary height of water in the proportion $1:3:3^2:3^3$ . . . If three mols. of methyl alcohol reduce the surface tension of water as much as one mol. of ethyl alcohol, the conclusion is justified that the tendency to increase the surface tension of water is three times less in the case of methyl alcohol than in the case of its nearest homologue. Hence the tendency of methyl alcohol to separate from the solution may be considered as three times less than the corresponding tendency of ethyl alcohol, or, in other words, the solution tension of substances belonging to homologous series, which exercise a strong influence on capillarity, increases with increasing molecular weight in the proportion $1:3:3^2:3^3$ . . . If a layer of a liquid insoluble in water, say benzene, be placed upon an aqueous solution of different alcohols, esters, &c., the amount of dissolved substance of which this liquid will deprive the water will be greater in exact proportion as the solution tension is less. Distribution coefficients and solution tension—and hence also surface tension and osmotic velocity—are therefore proportional magnitudes in first approximation.

Thus Overton's theory is erroneous in as far as it represents penetration into the cell as depending on the degree of lipoid solubility, for dissolution of the dissolved substance in the lipoids certainly does not take place. The motive force is the surface tension. Overton and Meyer have pointed out that the efficacious narcotics, anaesthetics, and antipyretics all belong to those compounds which penetrate their membranes rapidly. Rapid penetration into the cell seems to be the most essential condition for enabling a narcotic to exercise its effect on the interior of certain cells. Thus narcotics which differ materially in their chemical composition may possibly exercise their action in different cells, and this action may vary considerably even when exerted on one and the same species of cell. But if

narcotising substances of the same homologous series, such as the ordinary alcohols or the esters, be considered, we are brought to the conclusions that the cells acted on are all of the same species, that the action in the interior of the cell only differs in degree, and finally that this difference depends essentially and solely on the velocity with which the homologous substances penetrate into the cells. Now this velocity has been shown to be proportional to the depression of the surface tension of water by the dissolved substances, and hence we cannot but conclude that the same law holds good for the narcotic action of homologous substances as has been proved to be valid for surface tension, and approximately so for the distribution coefficient.

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2. *The Action of Organic Bases on Olefinic Ketonic Compounds.* *By* Dr. S. Ruhemann *and* E. R. Watson.

The authors have continued their investigation [1] of the behaviour of unsaturated ketonic compounds, especially of benzylideneacetylacetone, towards organic bases, and have isolated several additive compounds which are thus formed, *e.g.*, with m-toluidine, p-toluidine, m-chloroaniline, p-chloraniline, and β-naphthylamine. These substances on heating suffer the following decomposition:

$$C_6H_5.CH(NHR).CH(COCH_3)_2 = C_6H_5.CH : NR + CH_2(CO.CH_3)_2.$$

In some cases the additive compounds cannot be isolated, because they are decomposed at once, according to the above equation. Of interest is the fact that neither o-toluidine nor α-naphthylamine combines additively with benzylideneacetylacetone. Ortho-substituted benzenoid bases, therefore, seem not to react with the diketone. This conclusion is supported by the fact that piperidine readily forms an additive product with benzylideneacetylacetone, but tetrahydroquinoline does not.

The study of piperidobenzylacetylacetone, $C_6H_5.CH(N.C_5H_{10}).CH(COCH_3)_2$, has proved of the greatest interest as throwing light on the catalytic action of piperidine and other secondary bases in the condensation of aldehydes and ketones, which have been elaborated by Knoevenagel and his pupils. The authors arrive at the view that, taking the formation of benzylidenebisacetylacetone as example, the reaction is to be expressed thus:

$$(1)\ C_6H_5.CH : C(CO.CH_3)_2 + C_5H_{10}NH = C_6H_5.CH(N.C_5H_{10}).CH(CO.CH_3)_2.$$
$$(2)\ C_6H_5CH(N.C_5H_{10}).CH(CO.CH_3)_2 + CH_2(CO.CH_3)_2 = C_6H_5CH[CH(CO.CH_3)_2]_2.$$

The observation of Knoevenagel and Faber,[2] that ethyl benzylideneacetoacetate in the presence of diethylamine yields ethyl benzylidenebisacetoacetate, has also found a ready explanation. The fact that piperidobenzylacetylacetone on treatment with water yields benzaldehyde and benzylidenebisacetylacetone indicates that the formation of the latter substance is preceded by the production of an additive compound of the unsaturated ketone with the base.

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3. *The Union of Hydrogen and Oxygen in contact with a Hot Surface.* *By* William A. Bone *and* Richard V. Wheeler.

The authors have investigated the rate of formation of water when electrolytic gas, or electrolytic gas diluted with an excess of either hydrogen or oxygen, is circulated at a uniform speed over a porous surface, either of porcelain or magnesia, heated to 430° in the combustion tube of the 'circulation apparatus' described in our paper on the Slow Oxidation of Methane ('Trans. Chem. Soc.,' 1903, **83**, 1074). The steam was condensed each time the gases left the combustion tube, so that its rate of formation was indicated by the pressure-fall in the apparatus.

The experimental conditions were such that chemical change was exclusively

[1] Cf. *Trans. Chem. Soc.*, 1904, **85**, 466.

[2] *Ber.*, **31**, 2773.

confined to the layer of gas immediately in contact with the hot surface, and we therefore measured the rate of change in a heterogeneous system. Our results may be summarised as follows:—

1. With normal electrolytic gas the velocity of steam formation is always directly proportional to the pressure of the 'dry' gas in the apparatus. In other words, the velocity of chemical change is in no way determined by the 'order' of the reaction.

2. With excess of either hydrogen or oxygen the velocity of steam formation depends mainly, if not entirely, on the pressure of the hydrogen in the apparatus.

3. The catalysing power of the surface is always stimulated by previous exposure to hydrogen at 430°. Previous exposure of the surface to oxygen at the same temperature has the opposite effect.

4. The catalysing power of the surface is not affected by previous exposure to hydrogen at a red heat, followed by continued exhaustion at the same temperature. This proves that the stimulating effect of hydrogen at 430° is not attributable to a chemical reduction of the catalysing material.

5. At a red heat porous porcelain has the power of absorbing considerable quantities of hydrogen, of which only a part is yielded up on continuous exhaustion at the ordinary temperature.

6. The results are substantially the same, whether the catalysing surface be acid or basic in character.

The experiments indicate that the velocity of steam formation depends on an association of the hydrogen with the catalysing surface.

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4. *The Decomposition and Synthesis of Ammonia.* *By* Edgar Philip Perman, *D.Sc.*

It is well known that on heating ammonia a large proportion of it is decomposed, and it has been assumed by many chemists that the mixture then comes into chemical equilibrium. Some experiments recently carried out by Mr. G. A. S. Atkinson and myself appear to disprove the existence of any equilibrium in the case.

Decomposition of Ammonia by Heat.

In a recent communication [1] it was shown, from observations on the rate of decomposition of ammonia heated in a porcelain globe, that there is no equilibrium until complete (or nearly complete) decomposition has taken place.

Direct Synthesis of Ammonia by Heat.

In order to solve the question of equilibrium it was thought better to attempt to reach the equilibrium point (if one exists) by synthesis. A mixture of nitrogen and hydrogen (1:3) was passed slowly through a red-hot glass tube into dilute acid; on making the solution alkaline and testing for ammonia by Nessler's solution no trace was found. The result was similar when the tube was packed with broken porcelain. If, however, the mixture was passed over red-hot iron (and many other metals), or over asbestos, pumice, or clay tobacco-pipe stems, traces of ammonia were formed. These last-named substances contain iron, and it is concluded that there is no combination of the nitrogen and hydrogen unless some catalysing agent is present.

Decomposition and Synthesis of Ammonia by Electricity.

On sparking a mixture of nitrogen and hydrogen traces of ammonia were formed, and the gases came into equilibrium in about half an hour. Approximately the same equilibrium point was reached on decomposing ammonia by sparking, but when the volume was kept constant many hours' sparking were required to reach that point.

[1] *Proc. Roy. Soc.*, 1904, **74**, 110.

5. *On Active Chlorine.* *By* C. H. BURGESS *and* D. L. CHAPMAN.

The theory which postulates the formation of an unstable additive compound in the preliminary stages of chemical change has of late received considerable attention and support. It is claimed for this theory that it readily accounts for the remarkable influence of water vapour on the rate of chemical change, and also for the initial inert period which can be observed when a mixture such as hydrogen and chlorine is exposed to light. The theory in question cannot, in the opinion of the authors, be accepted as a complete explanation of the latter phenomenon, the chief objection to it being grounded upon certain quantitative results connected with the induction period with mixtures of carbon monoxide and chlorine and hydrogen and chlorine. In addition to carrying out work which has led to the above-mentioned conclusion, the authors have discovered several new facts of practical importance connected with the subject, which are briefly described below.

It is well known that hydrogen and chlorine inclosed in a Bunsen and Roscoe's actinometer over water do not immediately combine at their maximum rate when exposed to light.

In repeating this experiment of Bunsen and Roscoe it was found that, even after the maximum rate of combination had been reached, a fresh period of induction resulted on shaking the contents of the actinometer bulb. The period of induction produced in this way was not so long as the first period with the fresh gases. On again shaking the actinometer another induction period was observed still shorter than the second. By constantly repeating this operation and re-exposing to light, the contents of the actinometer were at last brought into such a condition that no fresh induction period resulted on shaking.

The experiment shows clearly enough that not only does a fresh mixture of hydrogen and chlorine on exposure to light change its condition in such a manner as to be ready to enter into combination, but that the aqueous solution of chlorine also alters, and ultimately becomes incapable of absorbing the activity of the mixed gases. Since the aqueous solution contains a considerable quantity of chlorine and very little hydrogen, it seemed probable that the change is mainly in the moist chlorine.

This was made the subject of a series of experiments. At first we were able to observe only a slight difference, somewhat similar to that noticed by Bevan in the behaviour of the insolated and uninsolated chlorine when mixed with hydrogen and exposed to light; but it was afterwards shown that, if proper precautions are taken to keep the chlorine in its active condition during admixture with hydrogen, combination occurs promptly on exposure to light. In accounting for the induction period the main fact to be taken into consideration is, therefore, the condition of the chlorine.

Our attention was next turned towards the discovery of all the possible methods of rendering chlorine gas and also its aqueous solution active. It was shown that chlorine gas becomes active when heated to 100° C. and then cooled, and also when it is acted upon by the silent discharge. An aqueous solution of chlorine can be rendered active, *i.e.*, incapable of absorbing the activity from active oxy-hydrogen gas, (1) by the action of light, (2) by contact with active chlorine gas, (3) by heating at a temperature of 100° C., and then allowing to cool.

The ability to remove the activity from chlorine is possessed in a much more marked degree by saline solutions and by acids than by pure water.

A solution of chlorine which has once been rendered active does not become inactive when the chlorine is removed in a vacuum. It can, however, be rendered inactive by dissolving in it certain salts such as crystallised barium chloride and fused calcium chloride. The foregoing observation suggested the possibility of preparing crystallised barium chloride both in an active and an inactive condition, and the following experiment showed that this could be done. An aqueous solution of barium chloride was rendered active by constantly shaking with chlorine in daylight; the chlorine was then removed in a vacuum, and the water distilled off *in vacuo.* The crystals thus obtained were dissolved in water which had been made active by contact with active chlorine. Another solution was made

by dissolving ordinary barium chloride crystals in a sample of the same water, and the two solutions were tested in two similar actinometers. The difference in the induction periods was so marked as to leave no doubt that soluble solids can be rendered active.

Preliminary experiments on the rate of decay of activity have shown that aqueous solutions retain their activity for a considerable period of time even when a current of air is passed through them. Barium chloride crystals, however, rapidly become inactive when they are exposed to the air for a few hours. It has also been observed that exposure of barium chloride to the action of radium rays does not render the salt active towards chlorine.

Besides establishing the above facts, the work, as mentioned above, includes comparative measurements of the induction period and of the sensitiveness of mixtures of hydrogen and chlorine, which appear to throw doubt on theories based on the assumption of the preliminary formation of additive compounds, which are formed and decomposed in conformity with the law of mass action.

The relation of the above facts to cloud formation has also been studied, but we have been unable to obtain any evidence of the formation of any intermediate substances in this way.

It has been incidentally observed that the presence of air does not prolong the induction period, although the sensitiveness of the mixture is thereby enormously reduced.

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6. *Exhibition of Effects produced by precipitating Silver Chromate in Gelatine. By* Professor I. TRAUBE.

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7. *Exhibition of Photographs of Sections of an Australian Siderite. By* Professor A. LIVERSIDGE, *F.R.S.*

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8. *Ueber Isocystein (Isothioserin). By* Professor S. GABRIEL.

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9. *Saponarin, a Glucoside coloured Blue by Iodine. By* G. BARGER.

The substance known to botanists as '*soluble starch*' and occurring in the leaf epidermis of a number of plants has been isolated from *Saponaria officinalis* at the suggestion of Professor L. Errera, of Brussels; it is a glucoside, and has been named *saponarin*. The substance is obtained pure in the shape of minute needles by a special method of crystallisation from mixtures of pyridine and water. Saponarin is insoluble in water and all ordinary organic solvents, but readily soluble in dilute alkalies and in pyridine; it melts at 231° with decomposition. The solution in alkalies is intensely yellow, and when acidified the substance remains for a long time in a state of pseudo-solution; in this condition it gives an intense blue or violet coloration with iodine dissolved in potassium iodide solution.

The air-dried crystals of saponarin lose water when heated or when left *in vacuo* over sulphuric acid. The dried substance is extremely hygroscopic, and, if left in the balance case for an hour or so, takes up quantitatively the water it had previously given off. For combustion it was dried *in vacuo* till of constant weight, and the boat containing it was then placed in a stoppered weighing tube. The mean of five analyses of the substance dried in this way gave

$$C = 53{\cdot}75\ \%.\ H = 5{\cdot}16\ \%$$

For the molecular weight determination pyridine was the only available solvent. The microscopic method was the most convenient, and gave the following result:

A solution of ·299 gram in 2·96 grams of pyridine was isotonic with a benzil solution of ·23 mole. Hence M = 436.

The two possible formulæ for saponarin are:

$$C_{19}H_{22}O_{11} \text{ requiring } C = 53{\cdot}52,\ H = 5{\cdot}21,\ M = 426$$
$$C_{21}H_{24}O_{12} \quad \text{,,} \quad C = 53{\cdot}85,\ H = 5{\cdot}13,\ M = 468$$

Of these, the second is considered the more probable, but a definite choice cannot be made till the decomposition products of the substance have been studied more fully. On boiling saponarin with mineral acids it is hydrolysed, and a yellow solution is formed, from which glucose was separated as phenyl glucosazone. Unless the solution be dilute, a second product of hydrolysis separates as a thick yellow oil, which has not yet been obtained crystalline. The name *saponaretin* is suggested for it, and it is scarcely soluble in water, but dissolves in alkalies and in pyridine; it closely resembles the parent substance, but does *not* give the reaction with iodine. From dilute solutions saponaretin separates in the solid state, either amorphous or in the form of imperfect whetstone-shaped crystals. It has not yet been obtained quite pure, but seems to be mixed with another substance which crystallises from alcohol in glistening plates.

The formula of the latter substance has not been definitely fixed owing to want of material, but it seems to be a hydrate of saponaretin.

Saponaretin is in all probability closely allied to the flavones. When fused with potash it yields *p*-oxybenzoic acid, and a red solution which gives the phloroglucin reaction with pinewood. Phloroglucin itself could, however, not be isolated.

The blue substance formed from iodine and saponarin exhibits a close analogy with that formed from iodine and starch. Its composition varies considerably, and it is another example of the absorption of iodine by a substance in pseudo-solution. The blue substance has been obtained in the crystalline state, but must nevertheless be regarded as a mixture and not as a chemical compound.

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10. *The Vapour Density of Hydrazine Hydrate.* *By* Dr. A. Scott, *F.R.S.*

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11. *The Combining Volumes of Carbon Monoxide and Oxygen.* *By* Dr. A. Scott, *F.R.S.*

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12. *The Action of Heat on Oxalates.* *By* Dr. A. Scott, *F.R.S.*

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13. *Some Alkyl Derivatives of Sulphur, Selenium, and Tellurion.* *By* Dr. A. Scott, *F.R.S.*

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14. *On the Presence of Arsenic in the Body and its Secretion by the Kidneys.* *By* W. Thomson, *F.R.S.E.*

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15. *On New Low-temperature Phenomena and their Scientific Applications.* *By* Professor Sir James Dewar, *F.R.S.*

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—AUBREY STRAHAN, M.A., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

[PLATE VIII.]

IT is forty-two years since the British Association last met in Cambridge, and we may turn with no little interest to the record of what was taking place at a date when the science of Geology was still in its infancy, and in a University where its promise of development was first recognised. Dr. John Woodward, the founder of the Woodwardian Chair, had been dead 176 years, but his bequest to the University had not long begun to bear fruit, for the determination to house suitably the collection of fossils and to provide for the reading of a systematic course of lectures was not arrived at till 1818. In that year Adam Sedgwick, on his appointment to the Woodwardian Chair, began a series of investigations into the geology of this country, which made one of the most memorable epochs in the history of British Geology. At the Cambridge meeting of 1862 he had therefore held the professorship for forty-four years, a period sufficient to spread his reputation throughout the civilised world as one of the pioneers of geological science.

Towards the close of his life Sedgwick gave expression to the objects which he had had in view when he accepted a professorship in a science to which he had not hitherto specially devoted his attention. 'There were three prominent hopes,' he writes, 'which possessed my heart in the earliest days of my Professorship. First, that I might be enabled to bring together a Collection worthy of the University, and illustrative of all the departments of the Science it was my duty to study and to teach. Secondly, that a Geological Museum might be built by the University, amply capable of containing its future Collections; and lastly, that I might bring together a Class of Students who would listen to my teaching, support me by their sympathy, and help me by the labour of their hands.'

We, visiting the scene of his labours more than thirty years after he wrote these words, witness the realisation of Sedgwick's hopes. The collection is not only worthy of the University, but has become one of the finest in the kingdom. It is housed in this magnificent memorial to the name of Sedgwick, on the completion of which I offer for myself, and I trust I may do so on behalf of this Section also, hearty congratulations to the Woodwardian Professor and his staff. Finally, I may remind you that at this moment the Directorship of the Geological Survey and the Presidential Chair of the Geological Society are held by Cambridge men; that the sister University has not disdained to borrow from the same source; and lastly, that it is upon Cambridge chiefly that we have learned to depend for recruiting the ranks of the Geological Survey, as proofs that Cambridge has maintained her place among the foremost of the British schools of Geology.

Though he had taken a leading part at former meetings of the Association, Sedgwick's advanced age in 1862 necessitated rest, and this Section was deprived

to a great extent of the charm of his presence. It benefited, however, in the fact that the Presidential Chair was occupied by one of his most distinguished pupils. Jukes was one of those men the extent of whose knowledge is not readily fathomed. It has been my experience, and probably that of many others in this room, to find that some conclusion, formed after prolonged labour and perhaps fondly imagined to be new, has been arrived at years before by one of the old geologists. Such will be the experience of the man who follows Jukes' footsteps. Turning to his Address given to this Section in 1862, we find much of what is now written about earth-movement and earth-sculpture forestalled by him, with this difference, however, that whereas the custom is growing of using a phraseology which may sometimes be useful, but is generally far from euphonious, and not always intelligible, he states his arguments in plain, forcible English.

It may raise a smile to find that Jukes thought it necessary in 1862 to combat the view that deep and narrow valleys had originated as fissures in the crust of the earth, and that the Straits of Dover must have been formed in this way, because the strata correspond on its two sides. But we shall do well to remember that the smile will be at the public opinion of that day, and not at Jukes himself. In no branch of Geology have our views changed more than in the recognition of the potency of the agents of denudation. In 1862 it was necessary to present preliminary arguments and to draw inferences which in 1904 may be taken as granted.

The evidences of the prodigious movements to which strata have been subjected, and of the extent to which denudation has ensued, cannot fail to strike the most superficial observer. Both mountain and plain present in varying degree proof that sheets of sedimentary material originally horizontal are now folded and fractured. But after a momentary interest aroused by some example more striking than usual, glimpsed, it may be, from a train-window, the subject is probably dismissed with an impression that such phenomena are due to cataclysms of a past geological age, and have little concern for the present inhabitants of the globe. These stupendous disturbances, it might be argued, can only have taken place under conditions different from those which prevail now. We are familiar with mountain-ranges in which their effects are conspicuous; we have carried railways over or through them and have been troubled by no cataclysmic movements of the strata. Apparently the rocks have been fixed in their plicated condition, and are liable to no further disturbance. Parts of the world, it is true, are subject to earthquakes accompanied by fissuring and slight displacement of the crust, but not even in earthquake regions can we point to an example of such thrusting and folding of the strata being actually in progress as have taken place in the past. Nor, again, can volcanic activity be appealed to, for some of the most highly disturbed regions are devoid of igneous rocks. Volcanic eruptions are more probably the effect than the cause of the disturbances of the crust. Nowhere in the world therefore, it will be said, can we see strata undergoing such violent treatment as they have experienced in the past. How, then, can we dispute the inference that the forces by which the folding was produced have ceased to operate?

Before accepting a conclusion which would amount to admitting that the globe is moribund and that the forces by which land has been differentiated from sea have ceased to act, we shall do well to look more closely into the history of the earth-movements to which any particular region has been subjected. The investigation is one which calls for the most intimate knowledge of the geological structure, and, as time will admit of my dealing with a small area only, I shall confine my observations to England and Wales, selecting such facts as have been established beyond dispute.

At the outset of the investigation we find reason to conclude that the movements, so far as any one region is concerned, have been intermittent. Evidence of this fact is furnished wherever any considerable part of the geological column is laid open to view. Sheets of sediment, aggregating perhaps thousands of feet in thickness, have been laid down in conformable sequence, all bearing evidence of having been deposited in shallow seas. The inference is inevitable that that period of sedimentation was a period of uninterrupted subsidence. But sooner or

later every such period came to an end. Compression and upheaval took the place of subsidence, and the strata lately deposited were plicated and brought within the reach of denudation. Illustrations of the recurrence of these movements abound, and I need dwell no further upon them than to remark that movements of subsidence and upheaval may be seen to have alternated wherever opportunity is afforded for observation.

On extending our observations we are led to infer that the movements of the crust were developed regionally, not universally. The areas of subsidence, for example, evidenced by the marine formations, had their limits, though those limits did not coincide with the shores of existing seas, nor has reason been found to believe that the proportion of land to sea has varied greatly in past times. The limits of the area affected by any one movement of upheaval are more difficult to determine, but the effects were manifested in the crumpling up of comparatively narrow belts of country, and are easy of recognition.

Further than this, we ascertain that the movements of one region were not necessarily contemporaneous with those of adjoining regions. The forces operating upon the crust of the earth came into activity in different places at different times, and, while some continental tracts have been but little disturbed from early geological times, there are parts of the globe which have been the scene, so to speak, of almost ceaseless strife. Among the latter we may include the British Isles.

These are commonplaces of Geology, and I mention them merely to emphasise the fact that the geological structure of these islands is the result of movement superimposed upon movement. Obviously, therefore, in order to gain a comprehensive view of the operations which were in progress in any one region during any one epoch, we have to find some means of distinguishing the movements of that epoch and of eliminating all which preceded or followed it. This, briefly, is the problem which has engaged the attention of geologists for many years past, and upon which I propose to touch.

The determination of the age of a disturbance is seldom easy, and among the older Palæozoic rocks is often impossible; but at the close of the Carboniferous period, during the great continental epoch which led to and followed upon the deposition of the Coal Measures, there came into action a set of movements of elevation and compression, which generally can be distinguished both from those which preceded them and from those which have been superimposed upon them. The distinction depends upon the determination of the age of the rocks affected by the movements. For example, a movement by which the latest Carboniferous rocks have been tilted from their original horizontal position is obviously post-Carboniferous. On the other hand, if Permian rocks lie undisturbed upon those tilted Carboniferous rocks it is equally obvious that the movement was pre-Permian. Now it happens that earth-movements of the date alluded to were particularly active in the British Isles, and played an important part in shaping the platform on which the Permian and later rocks were laid down. Though they have been more completely explored than others in the working of coal, their further investigation is of the greatest economic importance. I have attempted, therefore, briefly to sketch out the principal lines along which earth-movements of that age came into operation in England, premising, however, that by Permian I mean the Magnesian Limestone series, and not the 'Permian of Salopian type,' which is now known to be partly of Triassic but principally of Carboniferous age. In the course of the investigation we shall find reason to conclude that several at least of the movements followed old axes of disturbance, lines of weakness dating from an early period in the history of the habitable globe; and, again, that some of the latest disturbances of which we have cognisance were but renewals of movement along the same general lines.

One of the most clearly proved examples of pre-Permian faulting in the Carboniferous rocks occurs in the Whitehaven Coalfield. The fault forms the south-eastern limit of the Coal Measures, and has been precisely located for a distance of six miles. In its course towards the south-west it passes under five outliers of Permian rocks, and finally is lost to sight under the Permian and Trias of St. Bees.

The dislocation in the Carboniferous rocks amounts to about 400 yards, but the Permian rocks have not been even cracked; though broken and displaced by numerous faults of later date, they pass undisturbed over this great dislocation, the movement along it obviously having ceased before they were deposited. This fault forms part of the upheaval which brought the older rocks of Cumberland and Westmoreland to the surface, and in that sense it may be said to form the north-western frontier of the Lake District.

On the north-eastern side also of the Lake District the Permian rocks rest upon uptilted Carboniferous strata, but the axis of upheaval runs in a north-north-westerly direction and defines what we may regard as the north-eastern frontier. Along this frontier much movement has taken place in post-Permian times, but the unconformable relations of the Permian and Carboniferous rocks enable us to distinguish that part of the tilting which intervened between the two periods. On the south-eastern frontier also the Carboniferous rocks had been upheaved and denuded before the Permian sandstones were laid down. A huge fault, along which Carboniferous rocks have been jammed from the east in a multitude of plications against Silurian, runs from Kirkby Stephen by Dent to Kirkby Lonsdale, and thence trends south-eastwards by Settle. It is highly probable, though it has not been proved, that this fault is of pre-Permian age. That the Pendle axis which upheaves the Lower Carboniferous rocks between Settle and Burnley is pre-Permian is placed beyond doubt by the fact that an outlier of Permian rests upon the denuded crest of the anticline near Clitheroe.

The south-western frontier is defined by a still more marked unconformable overlap by the Permian strata, which here pass over the edges of the lowest members of the Carboniferous series and come to rest upon the Lake District rocks.

We have thus defined the sides of an oblong tract which was upheaved in the period we are considering. The older rocks forming the northern part of that tract had already had imposed upon them a dominant north-easterly strike by a pre-Carboniferous movement of great energy. As a result also of that and other movements they had been subjected to vast denudation, not only in the Lake District, but throughout the North-west of England generally. But while it is doubtful whether any of the physical features then produced have survived, it seems to be beyond dispute that it was in consequence of the pre-Permian movements that the older rocks of the Lake District were freed from their Carboniferous covering, and that to this extent the district may be said to have been blocked out in pre-Permian times. The detailed sculpturing resulted from later movements, with which we are not now concerned.

During this same period there rose into relief that part of the Pennine axis which runs between Lancashire and Yorkshire. The doming up of the Lower Carboniferous rocks and the wildness of the moorlands which characterise their outcrops have impressed all who have had occasion to cross from the one populous coalfield to the other, and have gained the name of the 'backbone of England' for this anticlinal axis. Whether, however, it can be regarded as one axis or as the result of several movements is doubtful, but not material for our present purpose. Regarded as a geological structure it is not continuous with that part of the Pennine axis which runs along the north-eastern frontier of the Lake District.

Passing westwards from the Pennine axis we cross the deep and broad Triassic basin of Cheshire, which may be regarded as the complement of the dome of elevation of Derbyshire. To the west of this, again, we reach a part of North Wales which was more or less shaped out by the earth-movements which came into action between the Carboniferous and Permian periods. Two leading faults traverse the district. The one runs in a north-north-westerly direction across Denbighshire and introduces that little bit of 'Cheshire in Wales' known as the Vale of Clwyd. Though there has been some later movement along this fault, it was in the main pre-Triassic, which statement, in view of the perfect conformity between the Permian and Trias, amounts to saying that it was pre-Permian. The other passes across Wales in a north-easterly direction along the Dee Valley at Bala, and reaches the Triassic basin between Chester and Wrexham. The date of this fault has not been worked out in detail, but the fact that it is associated with a pre-Triassic anticline,

where it reaches the Triassic margin, proves that it is in part at least of pre-Triassic age. In Anglesey also there has been strong post-Carboniferous folding in the same N.E.-S.W. direction.

It is to be noticed, further, that the Carboniferous rocks maintain their characters to their margins on the flanks of the Clwydian Hills and other ranges of Silurian rocks in North Wales. Both along the coast, and even in a little outlier preserved near Corwen by an accident of faulting, they show a persistence of type and of detail in sequence which could hardly have been maintained had the Silurian uplands existed in Carboniferous times. The inference that the uplands of Denbighshire and Flintshire are the result of post-Carboniferous upheaval is strengthened by the fact that the Carboniferous rocks reposing on their flanks are tilted at an angle which would carry them over their tops. This part of North Wales, therefore, presents a history corresponding in its main events with that of the Lake District. It had undergone elevation and denudation in pre-Carboniferous times on a scale so vast that rocks showing slaty cleavage and other indications of deep-seated metamorphism had been laid bare. But in both cases it was in consequence of the post-Carboniferous movements that the leading physical features as they exist to-day began to take shape.

In both these regions pre-Carboniferous movements had been extremely active. For example, an axis of compression and upheaval ranges from N.E. to S.W., involving the Lake District, the Isle of Man, and Anglesey. It belongs to the Caledonian system of disturbances which is developed on a large scale further north, and which sufficed here to cause slaty cleavage and presumably the extrusion of the Shap granite. I mention this pre-Carboniferous axis to point out that it offers an explanation of the direction taken by the post-Carboniferous disturbances of Whitehaven, Pendle, Anglesey, and possibly Bala. With the exception of the last-named they lie well within the region affected, and alone among the post-Carboniferous axes take that particular direction.

The Pennine axis ends as a physical feature in South Derbyshire and North Staffordshire on the margin of a deep channel filled with Triassic marl, which extends westwards from Nottingham into Shropshire. In this part of England there springs into existence a remarkable series of disturbances tending to radiate southwards. The westernmost of these is the great fault which forms the western boundary of the North Staffordshire Coalfield. Recent work by Mr. W. Gibson has shown that the vertical displacement of the Coal Measures amounts to no less than 900 yards, but that it is far less, though recognisable, in the Trias, proving that the disturbance was in the main pre-Triassic. The fault ranges from Macclesfield in a south-south-westerly direction, is lost to view under the Trias near Market Drayton, but is recognisable further on in the great dislocation which passes along the western side of the Wrekin, and thence through Central Shropshire by Church Stretton to Presteign in Radnorshire, and thence into Brecknock.

The second is the Apedale Fault of the North Staffordshire Coalfield. In working the coal this disturbance has been found to possess the structure of a broken monocline, a fold with fracture such as may be regarded as an early stage in the formation of an overthrust from the east. It runs through the coalfield in a direction slightly east of south, and then passing under the Trias of Stafford ranges for Wolverhampton and Stourbridge. This fault is mainly pre-Triassic, but what Mr. Gibson believes to be a continuation of it, following the same direction as far south as Hanbury, certainly effects a great movement in the Trias.

The third disturbance runs on the east of the Forest of Wyre Coalfield in a direction a little west of south. Here, as I learn from Mr. T. C. Cantrill, the thrust from the east is obvious, for Old Red Sandstone has been pushed from that direction against and even over Coal Measures, while the strata have been forced up into a vertical position for some miles. In South Staffordshire all the Carboniferous rocks, including the 'Salopian Permian,' are involved in this and the previously mentioned movement, proving that both disturbances were of post-Carboniferous date.

Traced southwards, this disturbed belt leads to Abberley, and there connects itself with the well-known Malvernian axis. The broken belt known by that

name runs north and south, and may be followed almost continuously from Worcestershire to Bristol. It presents evidence of having been a line of weakness through a large part of the world's history, as shown by Professor Groom, and of having yielded repeatedly to earth-stresses; but there is seldom difficulty in distinguishing the movements which were effected during the period under consideration. For example, near and south of Abberley the Coal Measures are clearly involved in a thrust from the east, which was sufficiently energetic to turn over a great belt of Old Red Sandstone and other rocks beyond verticality for some miles. Further south, again, among repeated proofs of the ridging up of the old axis in several pre-Carboniferous periods, we find evidence of post-Carboniferous elevation along the same general line. Throughout this same region there has been also post-Triassic dislocation, which, however, is on a comparatively small scale. That the Carboniferous rocks were greatly disturbed before the Trias was laid down is proved by the great unconformity between the two formations.

The Malvernian axis continues southwards by Newent, but perhaps with diminishing intensity. On its west side a broad syncline rolls in the tract of Carboniferous rocks which underlies the Forest of Dean. The syncline trends north and south, and is shown to be of pre-Triassic age by the fact that the Triassic strata on the banks of the Severn do not share in the synclinal structure. Here we must leave the Malvernian axis for the present.

The fourth disturbance ranges along the Lickey Hills, which, diminutive as they are, tell a story of great geological significance. They range in a south-south-easterly direction, and in the fact that they are formed of extremely ancient rocks furnish evidence of immense upheaval. From the relations of these ancient formations to one another we may gather also that the upheaval was due to a recurrence of movement along the same axis at more than one geological date, but at the same time we find no difficulty in distinguishing that part of the movement which took place between Carboniferous and Triassic times, for the Coal Measures are tilted up on end along the flanks of the axis, while the Trias passes horizontally over all the tilted rocks. A clue to the southward extension of the axis under the Secondary rocks is furnished by some faulting as far as Redditch, here also there having been a renewal of movement on a small scale in post-Triassic times.

The fifth disturbance runs through Warwickshire and includes the low ridge of ancient rocks which ranges through Atherstone and Nuneaton in a south-easterly direction. About fifteen miles to the north-east Archæan rocks form the parallel ridge or series of ridges of Charnwood Forest, while the intervening space is overspread by Trias, resting partly on Carboniferous and partly on older strata. The structure of the Carboniferous and older strata is dominated by what is known as the Charnian movement, which includes disturbances of several ages ranging in a south-easterly direction. That part of the movement which was post-Carboniferous is identifiable by the fact that Coal Measures are tilted on either side of the ridges of old rocks. They once overspread both ridges, but were removed by denudation as a consequence of upheaval before the Trias was deposited. It has been found also in working the coal, as I am informed by Mr. Strangways, that there are large faults having the south-eastward or Charnian direction which shift the Coal Measures, but do not break through the overlying Trias. The evidence, therefore, of a great Charnian movement having taken place during the period under consideration is conclusive. The disturbance ranges as a whole in the direction of Northampton, where in fact borings have reached the Charnwood rocks at no great depth.

The five great disturbances which I have briefly indicated tend to converge northwards, but their exact connection with the Pennine axis is not known. What may be only a part of that axis trends for Charnwood through a tract of Lower Carboniferous rocks exposed at Melbourne, between the Yorkshire and Leicestershire Coalfields, but the Triassic channel I have already mentioned intervenes, and the structure of the rocks underlying the red marl is unknown. The channel itself appears to be of Triassic age, for not only is the depth of marl in it suggestive of its having been a strait in the Triassic waters but its northern margin has been

found by Mr. Gibson to coincide with, and perhaps to have been determined by, faults known to be mainly of pre-Triassic age. One of these, with a downthrow of 400 yards to the south, runs from Trentham through Longton, and south of Cheadle, while another ranges from near Nottingham to the north of Derby.

We come now to the south-west of England, where we find striking proofs of a still more energetic movement than any yet mentioned having intervened between the Carboniferous and Triassic periods. The central part of the Armorican axis, as it has been called, after the ancient name of Brittany, trends nearly east and west, and keeps to the south of our South Coast; but we have opportunities in Devon and Cornwall of seeing some of the stupendous effects produced along its northern side. A belt of country measuring some 130 miles in width has been completely buckled up. Slaty cleavage was superimposed upon the intricate folds into which the strata were being thrown, while after or towards the close of these phenomena granite was extruded at several points along the belt of disturbance, a little north, however, of the line along which the oldest rocks were brought up to the surface. In Devon the Culm-measures are fully involved in the movement, but on the other hand the Permian strata, while containing fragments of the cleaved and metamorphosed rocks, are themselves wholly free from such structures. The age of the folding, cleavage, and extrusion of the granite is thus definitely fixed as having been subsequent to the deposition of the Culm-measures, but previous to that of the Permian rocks.

But we may fix the age still more closely. A broad syncline of Carboniferous rocks traverses Mid-Devon, and is succeeded northwards by an anticline and by an extrusion of granite at Lundy Island, the age of which, however, has not yet been definitely ascertained. Still further north in a series of folds and overthrusts which traverse the southern margin of South Wales we can recognise the last effects of the great Devonshire movement at a distance of not less than 130 miles from the central axis, the ground-swell, so to speak, subsiding as it receded from the distant storm-area. Here the higher Carboniferous rocks are involved, and thus prove that this part at least of the Armorican disturbance was of post-Carboniferous age.

In Dorset, Somerset, and Gloucestershire the Palæozoic rocks pass eastwards under Secondary formations, and are seen no more in the South of England. That the disturbance continues, however, is inferred from the fact that it has been traced across a large part of the continent of Europe in the one direction and across the South of Ireland in the other. The determination of its position therefore, and especially of the effects of its intersection with the Midland disturbances, is of the greatest importance in view of the possible occurrence of concealed coalfields under the Secondary rocks. One such intersection is open to observation.

The Malvern and Devonshire disturbances intersect in Somerset. On investigating their behaviour as they approach we may notice in the first place that the subsidiary axes which form the northernmost part of the Devonshire disturbance in South Wales die away one after the other towards the east. Thus an east and west disturbance at Llanelly runs a few miles and disappears. The more important Pontypridd anticline, which traverses the centre of the coalfield, fades away near Caerphilly, while the coalfield itself terminates a little further east, its place on the same line of latitude being taken by the Usk anticline, which trends southwards and south-westwards. So far it might be inferred that the east and west folds die away on approaching the north and south Malvernian axis. But the Cardiff anticline, which lies south of and was more energetic than those mentioned, crosses the Bristol Channel and, emerging on the other side in a complicated region near Clevedon and Portishead, passes to the north of Bristol and holds its course right across the coalfield at Mangotsfield. The coalfield, however, lies in what is part of the Malvernian disturbance, for it occupies a syncline running north and south along the west side of the main axis of upheaval. Though the interruption is local and the strata recover their north and south strike to the south of it, yet the east and west axis obviously holds its course right through the Malvernian structure.

Still further south in the direction in which the east and west movements

gradually increase in energy a series of sharp folds is well displayed in the coast of South Wales and in an island in the Bristol Channel, ranging for that part of the east and west disturbance which is known as the Mendip axis. This name has been applied to a series of short anticlines which are arranged *en échelon* along a line ranging east-south-east, but each of which runs east and west. Among them we may distinguish the Blackdown anticline, the Priddy anticline, the Penhill anticline, north of Wells, and the Downhead anticline, north of Shepton Mallet. With one exception they all die out eastwards after a course of two to ten miles, but the Downhead anticline holds its course into the Malvernian disturbance, the two engaging in a prodigious *mêlée* south of Radstock. From that much shattered region the Downhead anticline emerges, but the Malvernian axis is seen no more, and, so far as can be judged under the blanket of Secondary rocks, comes to an end.

Mention has been made of the fact that many of the subsidiary east and west folds die away on approaching the Malvernian axis. In a general way we may attribute their disappearance to the influence of the north and south movement, for it is commonly to be observed in these great belts of disturbance that they are composed of a number of parallel anticlines or elongated domes of upheaval, constantly replacing one another; it is a common feature also that these subsidiary folds replace one another not exactly in the direction in which they point, but that they lie *en échelon* along a line slightly oblique to it. The behaviour of the South Wales and Mendip folds is in accordance with these observations, and may be taken to indicate that the effects of the east and west disturbance reached further north in South Wales than they did in Somerset, or, in other words, that they failed to penetrate as far into the region where north and south movements were in progress as in the region where there were no movements of that direction.

The fact that the east and west folds keep their course across the north and south wherever the two actually meet comes out prominently, and supports the inference that they dominate the structure of the Palæozoic rocks which lie hidden beneath the Secondary rocks of the south and south-east of England. Somewhere under this blanket of later formations the east and west axis presumably intersects the other disturbances which traverse the Midlands. To ascertain where and how the intersections take place will be going far towards locating any concealed coalfields which may exist; but the knowledge can be obtained only by boring, and the number of such explorations as yet made is wholly insufficient. The majority have been made in search of water, and have been stopped as soon as a supply was secured. Near Northampton the older rocks were reached at a small depth on what is believed to be the underground continuation of the Charnian axis, and a boring at Bletchley traversed what is thought to have been a great boulder of Charnian rock, suggesting that the axis is not far off; but with these exceptions the counties of Oxford, Buckingham, Bedford, Huntingdon, Cambridge, and Norfolk are unknown ground. Yet under these counties the axes must run if they keep their course. Where exposed at the surface each post-Carboniferous syncline between two axes contains a coalfield. It remains to future exploration to ascertain whether similar conditions hold good under the Oolitic and Cretaceous areas of Central England.

In speaking of the north and south disturbances I have in more than one case stated that the post-Carboniferous movement was but a renewal of activity along an old line of disturbance. The fact is proved by the unconformities visible among the pre-Carboniferous rocks, and it is important for the reason that the geography of this part of the globe at the commencement of the Carboniferous period had been determined by these movements. It has long been known, for example, that the parts of the counties of Stafford, Warwick, and Leicester traversed by the axes of upheaval were not submerged till late in the Carboniferous period. On the other hand, some of the area lying immediately west of the Malvernian axis was submerged at an earlier date, as is shown by the existence of Carboniferous Limestone at Cleobury Mortimer and, in greater development, in the Forest of Dean. The borings near Northampton also proved the presence of Carboniferous Limestone, a fact which is in favour of the occurrence of concealed coalfields, in so far as it indicates that the whole Carboniferous series may have once existed there.

It is remarkable that none of the borings in the South and East of England have touched Carboniferous Limestone, all having passed into older or newer rocks. The existence of that formation is neither proved nor disproved.

The determination of the age of these disturbances and a discussion of the pre-Carboniferous geography may seem at first sight to be only of scientific interest, but that problems of great economic importance are involved has been shown recently. It has long been known that the principal coal-seam of South Staffordshire deteriorates westwards as it approaches the pre-Carboniferous ridge evidenced in the neighbourhood of Wyre Forest. There seemed, however, to be no theoretical reasons why it should not keep its characters on either side of the fault which forms the western boundary of the South Staffordshire Coalfield, inasmuch as that fault came into existence after the deposition of the Coal Measures. A shaft recently sunk has proved the correctness of the inference. The seam has been found to be well developed to the west of the fault, and a considerable addition has been made to our productive coalfields.

So much has been written about the range of the Devonshire disturbance under the South of England that I shall add no more than a brief comment on some of the evidence on which reliance has been placed. We have seen that there has been some post-Triassic movement along old lines of disturbance in North Wales and the Midlands and along the Malvern axis. It is suggestive therefore to find that in the region which we believe to be underlain by the east and west disturbance east and west folding forms the dominant structure of the Secondary and Tertiary rocks.

The anticlines of the Vales of Pewsey and Wardour, the London syncline, the Wealden anticline, the Hampshire syncline, and the anticline of the Isles of Wight and Purbeck, not only lie in the range of the axis, but show an increasing intensity southwards, towards what we may suppose to have been the most active part of that axis. A similar structure prevails in the Oolitic rocks also. They too had been thrown into east and west folds before the Cretaceous period, and this earlier set of movements also grew in intensity towards the south. It would seem, then, at first sight that the structure of the later rocks gives an easy clue to the structure of the older rocks buried beneath them. This is by no means the case. That the movements manifested in the Oolitic and Cretaceous rocks followed the same general line as the older movement admits of little doubt, but that the later structures correspond in detail with the earlier is improbable.

A brief examination of the region where the Carboniferous rocks disappear under the Secondary formations will give the grounds for this statement. There we find that the Trias passes over the complicated flexures of the Mendip axis in undulations so gentle as to prove that those flexures had been completed before it was deposited. Nor again do the members of the Oolitic group of the rocks cropping out in succession further east show any such folds as those visible in the Carboniferous, and it is not till we have passed over a considerable tract of Secondary rocks in which there are no signs of east and west folding that we reach the anticlines of the Vales of Pewsey and Wardour. Nor can we then fit these folds in the Cretaceous formation on to any visible axes in the Carboniferous rocks. Under these circumstances it would be unjust to suppose that such synclines and anticlines as those of the London and Hampshire basins, or of the Weald, coincide with previously formed synclines and anticlines in the older rocks. They give a clue to the position of the old axis, but not necessarily to the details of its structure. Yet it is upon the determination of the position of the older anticlines and synclines, and of their intersection with the north and south disturbances, that we must depend for locating concealed coalfields. So far but little has been done in the forty-eight years since the question was first mooted by Godwin-Austen. The existence of a coalfield in Kent has been proved, and what appears to be a prolongation of a disturbance from the Pas de Calais along the south-western side of it. The other borings which have reached the Palæozoic floor round London and at Harwich have thrown but little light on the details of its structure. By far the greater part of the ground remains yet to be explored.

In this brief review of the earth-movements of one period, as manifested in one

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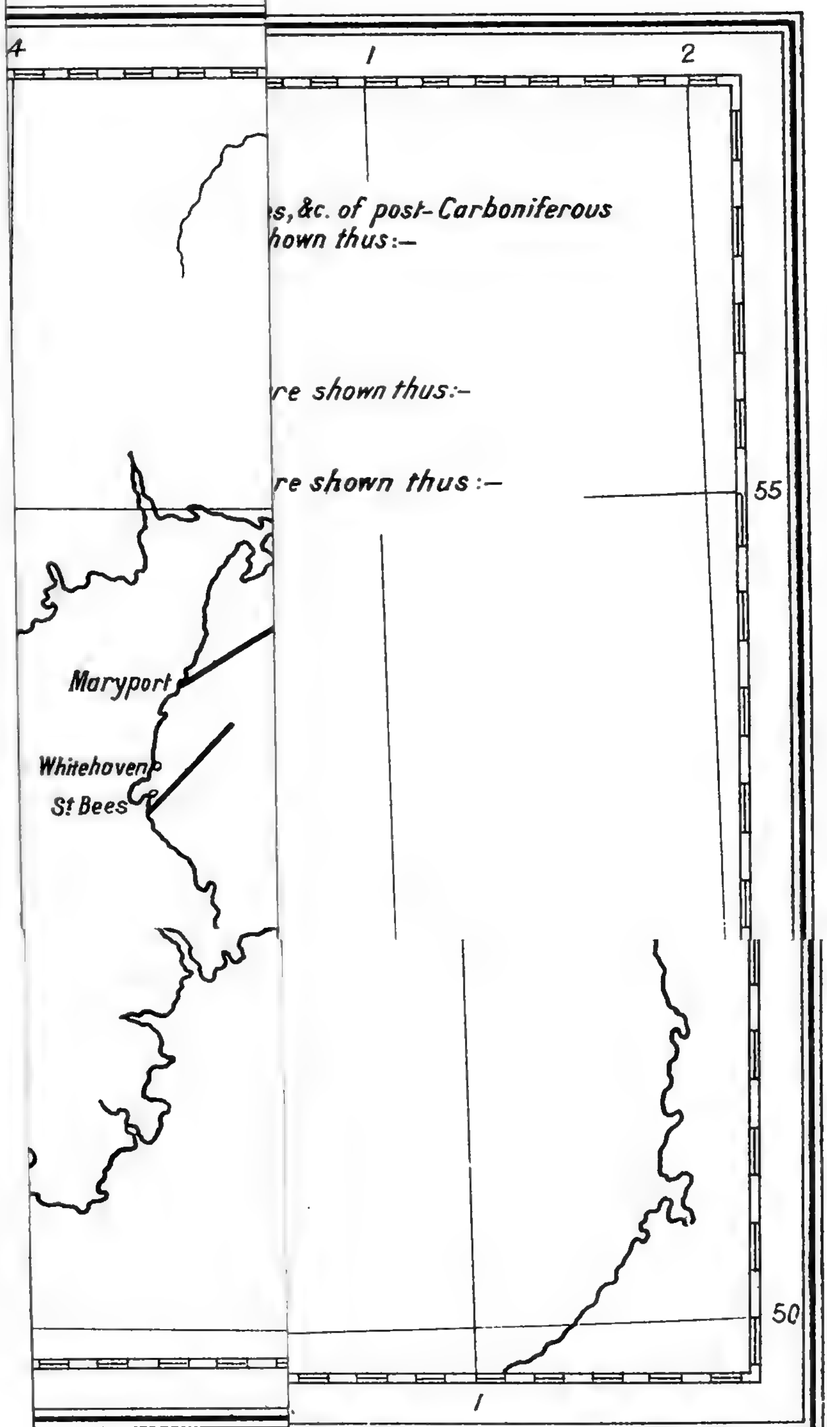

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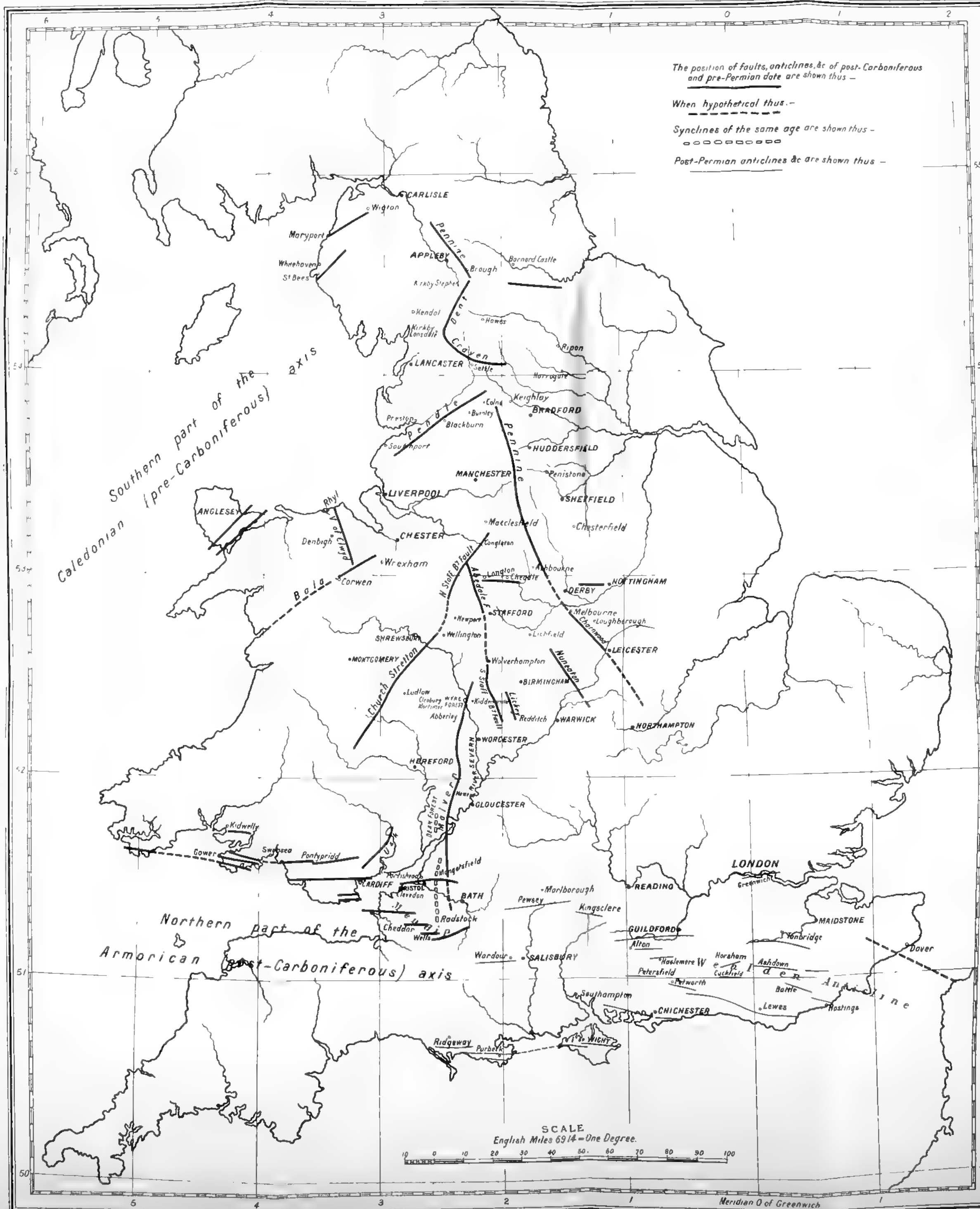
MAP OF POST-CARBONIFEROUS AND PRE-PERMIAN EARTH-MOVEMENTS.

By A. Strahan, M.A., F.R.S.



Illustrating Mr. Strahan's Address to the Geological Section.

small part of the globe, we have found reason to conclude that they were the result of compression and upheaval; that the crust yielded to the compression by overthrusting and buckling along certain belts; that these belts in the North of England and the Midlands ran for the most part north and south, diverging, however, to the south-west and to the south-east, while in the South of England they took an east and west direction and concentrated themselves along a belt of country which presents the phenomena of crushing on a stupendous scale. We have touched in two cases the flanks of a mountain-range—the Caledonian, which was built and ruined before the Carboniferous period; the Armorican, which was built after that period, and which, though it has stirred so recently as the late Tertiary period, and so energetically as to initiate the physical features and river-system of the South of England, yet expended the greater part of its energy before the Permian period. Lastly, we have found evidence, in the majority of cases, that the disturbances were but renewals of movement along lines of weakness long before established, and that in several cases there has been further renewal along the same lines during successive periods later than the one we have considered. With such a history before us, and with the knowledge that mountain-ranges have been built in other parts of the world by the upheaval of strata of almost recent date, we have more cause to wonder that the internal forces have left this quarter of the globe alone for so long, than reason to believe that they have ceased to exist. Changes of level, however, have taken place in comparatively recent times, and are now in progress. Though almost imperceptibly slow, they serve to remind us that a giant lies sleeping under our feet who has stretched his limbs in the past, and will stretch them again in the future. Nor in view of the fact that the structures I have described have only been revealed by the denudation of vast masses of strata does it seem unreasonable to suppose that they are deep-seated phenomena. The slow changes of level may be the outward manifestation of more complicated movements being in progress at a depth.

It is interesting to speculate on what appearance the globe would have presented had it not been enveloped in an atmosphere and covered for the most part with water. Owing to those circumstances it possesses the power of healing old wounds and burying old scars. In their absence we may suppose that the belts of crushing and buckling would have given rise to ridges growing in size at every renewal of movement, for they would have been neither levelled by denudation nor smoothed over by sedimentation. This globe, we may suppose, would have appeared to the inhabitants of another planet as being encompassed in a network, and we are prompted to ask whether our astronomers can distinguish in any other planet markings that may be attributable to this cause. I must remind you, however, how much more remains to be done than I have been able to touch upon to-day. The map represents one episode only in a long series of events, and a series of such maps would be required to illustrate the first appearance of lines of weakness in the earth's crust, the subsequent renewals of movement along those lines, and the formation of new lines in successive geological periods. With the case thus set out we shall be justified in appealing to the physicists for an explanation of the restlessness of this globe.

The following Papers and Report were read:—

1. *The Geology of Cambridgeshire.* *By* J. E. Marr, *Sc.D., F.R.S.*

The main physical features of the county are the Chalk uplands of the south-eastern and southern part, the curious plateau on the west, the Cam Valley between them, and the fenland of the north.

Of Jurassic rocks, the Oxford Clay is not well exposed save near Whittlesea. The Corallian rocks are of considerable interest. Two types occur—the Ampthill Clay facies of the western outcrop and the Calcareous facies of the Upware Inlier. The Elsworth rock forms the base of the deposits of each of these types, and its relationship to the members of the Calcareous facies is a subject still under discus-

sion. The Upper and Lower Kimmeridge Clay are found at Ely and in the neighbourhood of that city.

Of Cretaceous rocks the Lower Greensand is well seen near Gamlingay. The old phosphate workings of Wicken are now closed. The Gault is seen in many exposures. Most of the sections exhibit Lower Gault, but Mr. Fearnsides has recently detected the Upper Gault in the Barnwell brick-pit. The basal member of the Chalk, the well-known Cambridge Greensand phosphatic seam, lies unconformably upon the Gault. It is succeeded by various divisions of the Chalk up to the zone of *Micraster*.

The glacial deposits consist chiefly of the chalky boulder clay; the great boulder at Ely is of interest.

The Pleistocene gravels include the plateau gravels on the chalk hills and the well-known mammaliferous gravels forming terraces on the valley-sides. The March marine gravels are usually correlated with the gravels of one of these terraces.

Alluvium is found on the valley-bottoms, and in the fenland peat occurs with intercalated patches of *Scrobicularia* clay. The peat contains the fauna of Neolithic and later times.

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2. *The Great Eastern Glacier.* *By* F. W. Harmer.

This name is proposed for the great ice-stream, the moraine of which, the chalky Boulder Clay, covers an area of more than 5,000 square miles in the East of England, frequently attaining a thickness of more than 100 feet.

As far back as 1858, Trimmer, a pioneer in glacial investigation, had pointed out that the county of Norfolk had been twice invaded by ice, first from the North Sea and then from the west, the resulting detritus in the one case being characterised by igneous blocks, some of them of Scandinavian origin; and in the other by a predominance of Jurassic material. The first invasion is represented by the Cromer Till and the contorted Drift of the Norfolk coast; the second, which does not occur in north-east Norfolk, by the chalky Boulder Clay, the subject of the present paper.

The region covered by the latter deposit, which extends over a great part of the eastern counties of England, has a palmate outline, its lobes, which radiate from the great depression of the Lincolnshire and Cambridgeshire Fens, being of unequal length. The latter region was not only the centre whence the chalky Boulder Clay was distributed, but also the quarry out of which was excavated the enormous mass of Jurassic material forming to a great extent the matrix of this deposit.

The present physiographical features of the East of England closely resemble those which obtained in glacial times, the Drift deposits not only covering the plateaux between the valleys in which the rivers of the district now run, but descending into them, sometimes to below sea level. Hence by the study of the existing contours, aided by that of well-borings, it is possible to obtain a general idea of the preglacial topography by which the movements of the ice must have been influenced.

Although the erratics of the chalky Boulder Clay are more or less of a similar character over a wide area, indicating that it was distributed from a common centre, its predominant character varies in different districts, in accordance with that of the strata over which the ice moved. The matrix of the Boulder Clay of south Norfolk and north Suffolk, for example, has been largely derived from the Kimmeridge Clay. Over this region, which formed in glacial times a shallow trough running east and west, corresponding with the present depression of the basins of the Little Ouse and the Waveney, as well as with the gap in the Chalk escarpment between Swaffham and Newmarket, the ice evidently poured in great volume, planing down the surface of the Chalk and carrying its Kimmeridgian material fifty miles to the east from its original source in the Fen basin. On the other hand, although the Fen ice was sufficiently thick to enable it to overflow

the Chalk hills between Newmarket and Royston, it only travelled thence to the south-east for about half that distance. In this region the Boulder Clay is chalky near the escarpment, while beyond the outcrop of the London Clay it is mainly composed of detritus from that formation.

Along the basin of the Ouse, where its matrix is largely Oxfordian, the ice to which it was due advanced much further, to Buckingham and beyond, as it also did along that of the Nene, in the direction of Northampton. On the contrary, the high land near the head waters of the Welland obstructed the ice-flow, so that but little Boulder Clay seems to have found its way into the area comprised in sheet 53 of the Ordnance map. The greater part of sheet 63, however, is covered by it, and it there reaches an elevation of 730 feet above the sea level. Much of the Boulder Clay of this region, in the author's opinion, was due to the ice-stream of the Trent Valley having been piled up upon the high land to the east of Leicester by the pressure of ice descending from the Pennines.

It seems probable that the whole of the low-lying region between the Lincolnshire Wolds and the Pennines was filled with ice during the period of maximum glaciation. It is not physically possible that any considerable thickness of ice could have existed on one side only of the Lincolnshire ridge, which does not often exceed an elevation of about 200 feet above the lower ground adjoining it. The author hopes to make the ultimate source of the chalky Boulder Clay ice the subject of a future paper. The prevalence of Carboniferous *débris* in the East Anglian region seems to indicate, however, that a part of it at least was of Pennine origin; another part may have been due to an overflow from the North Sea across the lowest part of the Chalk Wolds, and the ice may also have been reinforced by the abundant precipitation to which this district was subject during the Glacial period; the moisture-bearing cyclonic disturbances from the Atlantic, to which the enormous accumulation of ice in the Baltic region was due, must have passed near the eastern counties of England. There is no evidence to show that any considerable amount of ice entered East Anglia through the Wash gap, all the facts known to the author appearing to point in an opposite direction.

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3. *On a Great Depth of Drift in the Valley of the Stour.* *By* W. WHITAKER, *F.R.S.*

Several cases of great irregularities in the thickness of the Drift have been shown by borings in Suffolk, where the existence of deep channels filled with Drift has been practically proved, as also in the neighbouring counties of Essex and Norfolk. In some cases these channels cannot be shown on the map, the Glacial Drift being hidden by deposits of later age, and this is markedly the case in the upper part of the valley of the Cam, where at one place (Newport) the Drift has been pierced to the depth of 340 feet without reaching the bottom.

In Suffolk the greatest amount of Drift recorded is at Brettenham Park, where apparently a thickness of 312 feet has been found. But this and all other records in East Anglia are now put into the shade by the result of a boring near Glemsford railway station. This is at a low level in the valley of the Stour, in the tract formed by the sand and gravel that crops out from beneath the Boulder Clay of the higher ground. Here one would have expected, perhaps, some 50 feet of Drift; but certainly not more than 100. No less than 477 feet have been passed through, before reaching the Chalk.

The gravel and sand that form the surface reached to a depth of 51 feet, as might have been expected; but then the unexpected occurred, no less than 228 feet of boulder clay (partly sandy) having been found, with a mass of sand and clayey sand beneath.

We seem here then again to have evidence of a very deep Drift-filled channel. A well in the village, at a higher level, has reached Chalk after passing through 120 feet of Drift; so the channel does not reach far northward, nor does it reach to Foxearth, in Essex, about a mile to the south, where there is a still less thickness of Drift. As to its direction or extent, however, we can say little as yet.

One may add that a boring (? unfinished) in Euston Park has proved over 150 feet of Drift, at a spot where no Drift is shown on the map. This may be simply a huge pipe.

4. *Well-sections in Cambridgeshire.* *By* W. WHITAKER, *F.R.S.*

See Reports, p. 266.

5. *Note on a Small Anticline in the Great Oolite Series at Clapham, north of Bedford.*[1] *By* HORACE B. WOODWARD, *F.R.S.*

Attention was drawn to a gravel-pit between Oakley and Clapham, in which a small anticline of the Great Oolite had been abruptly encountered amidst the regularly stratified river-deposits. The trend of the fold was N.N.W. and S S.E., and therefore contrary to that of the minor undulations which affect the Oolitic rocks of the district, and which serve to counteract the general dip of these strata between Sharnbrook and Bedford. Prior to the opening of the pit there was no surface-indication of the disturbed rocks, but the arch was coated with Great Oolite clay which had superficially been disarranged and mixed with gravel. There was no evidence to connect the disturbance with glacial action, nor was there any direct evidence against such a supposition. The Oolitic strata may have been planed down prior to or during the period of maximum glaciation, when the boulder clay, which crowns the adjacent plateau, was laid down. The erosion of the softer strata flanking the arch of Great Oolite limestone may have been due to the action of the river, the harder rocks having stood up as a low ridge until levelled up by the accumulation of the valley deposits. A portion of a molar of *Elephas primigenius* was obtained from the gravel; also a somewhat decomposed block of rhomb-porphyry, evidently derived from the boulder clay. The occurrence of this Scandinavian rock was of interest, as, according to Professor P. F. Kendall, it had not been previously found south of Norfolk.[2]

6. *Recent Coast Erosion in Suffolk—Dunwich to Covehithe.* *By* JOHN SPILLER.

This communication brings up to date the record of losses on the Suffolk coast, and continues the Report presented at the Ipswich meeting, 1895, of which details were published in the 'Geological Magazine' for January 1896. Since that time scarcely a year has passed without the winter gales and high tides doing mischief at one or more points of the coast embraced within the limits above specified; but whilst Lowestoft and Pakefield, Covehithe, and Easton have all suffered very considerably, the cliffs at Dunwich, until quite recently, remained almost unaffected.

The losses may be summed up as follows:—

Dunwich.

All Saints' Church Ruins and Graveyard.—The 43 feet of land reported by Mr. Whitaker, September 1880,[3] became 25 feet by Mr. Teall's measurement in 1902. Now this has all gone and about 6 feet of northern buttress and east end of the Church have dropped into the sea. Total loss, 31 feet in two years.

Footpath at Temple Hill.—Mr. Whitaker says, '40 yards outside the wood.' Mr. Teall in 1902 made it 38 yards. It is now diminished to 59 feet. Actual loss, therefore, 55 feet in two years. The cliffs extending away north and south

[1] Printed in full in the *Geological Magazine*, Decade V., vol. i. pp. 439–441.

[2] See Eighth Report of Committee on Erratic Blocks, *Rep. Brit. Assoc.* for 1903.

[3] See Memoir of the Geological Survey, *Southwold and the Suffolk Coast*, by W. Whitaker, F.R.S., p. 48.

have lost more than this, except at Misner. The lifeboat at the Coastguard Station cannot be used at present, for the shingle beach is gone and the boathouse perched on a terrace. Ordinary tides reach the foot of the cliffs, and further losses may be expected.

Walberswick.

The high shingle beach is cut back all the way from Dunwich to the mouth of the river Blyth.

Southwold.

As the result of lengthening the old North Pier at the harbour a good deal of sand and shingle has been thrown up, but not enough to replace that lost in front of the lifeboat house, which is now practically useless and embanked for further protection. It has been suggested that another 50 feet might be added on to the Pier, and that the old jetty near the centre cliff should be reconstructed.

The timber breastwork in front of the town has stood well since it has been continued to Buss Creek and strengthened at critical points by double piling. The new pier, 880 feet long, erected by the Coast Development Company at the North Cliff has acted like a groyne, and vastly increased the beach on both sides of it, so that the Bathing Station, threatened with destruction in 1895, is better than ever.

Easton.

The low land extending from Buss Creek to the southern slope of Easton Cliff remains as before, protected by a huge bank of shingle, but from this point onward to the Broad great losses have occurred. The site of the gun battery is buried out at sea, and the powder magazine behind it now left in ruins on the shore, 50 feet outside the present edge of cliff. The rifle range has been shortened by 100 yards and a new butt constructed, so that the total loss may be estimated at 350 feet since 1895. The effect of this demolition is to bring Covehithe Ness into view, whereas it was formerly invisible from Southwold. Another necessary consequence is that the coast line, straight in the Ordnance map, has once more become curved inwards, corresponding with the original Sole Bay. The seam of shelly crag at the foot of Easton high cliff was uncovered a year ago for the length of 40 yards, but is now entirely hidden by masses fallen from the cliff. The measures of loss (nine years) are as follows:—

Easton Cliff, southern end	350 feet.
Roadway, Easton Bavents	163 „
Easton high cliff	77 „

Covehithe.

Beyond Easton Broad the cliffs leading to Covehithe are constantly presenting new faces with bright yellow and pink colouring, suggestive of Alum Bay. The losses would probably have been greater but for ledges of hard sand rock, projecting out some 12 to 15 feet and acting as benches for the support of the upper strata. At Covehithe roadway frequent measurements have been taken since 1895, showing gradual diminution in length from 62 yards to a remnant of 19 yards. Total loss in nine years = 129 feet.

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7. *Report on the Fossiliferous Drift Deposits at Kirmington, Lincolnshire, &c.*—See Reports, p. 272.

FRIDAY, AUGUST 19.

The following Papers and Reports were read :—

1. *On the Structure of the Silurian Ophiurid* Lapworthura Miltoni. *By* Professor W. J. SOLLAS, *F.R.S.*

The structure of the arms and jaws of this fossil were described from information obtained by a study of serial sections, and reconstructions built up from these were exhibited before the Section.

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2. *The Base-line of the Carboniferous System round Edinburgh. By* B. N. PEACH, *LL.D., F.R.S., and* J. HORNE, *LL.D., F.R.S.*

In the last edition of the Geological Survey map embracing the Edinburgh district (Sheet 32), published in 1892, strata of Upper Old Red Sandstone age are represented as occupying the area that stretches southwards from the Castle by Morningside and Newington to the Lower Old Red Sandstone volcanic rocks of the Blackford Hill and Braid Hills. The rocks consist of conglomerates, red sandstones, marls, and cornstones. The correlation of these strata with the Upper Old Red Sandstone was based, not on fossil evidence, but partly on their lithological characters, and partly on the fact that along their eastern margin they pass conformably upwards into the Cementstone group of the Carboniferous system.

The Cementstone group as developed in the Edinburgh district consists of grey, green, and red mudstones, and shales with cementstone bands, occasional sandstones, and rarely some thin seams of dark carbonaceous shales yielding plants, ostracods, and Palæoniscid fish-scales of undoubted Carboniferous type.

In the last edition of the Edinburgh sheets all the beds between the Castle and the volcanic rocks of Arthur's Seat were included in the Calciferous Sandstone series. Our colleague, Mr. Goodchild, however, suggested that the sandstone underlying the dolerite sill of Salisbury Crags is of Upper Old Red Sandstone age in virtue of the cornstone associated with it, which in the Edinburgh district is characteristic of that formation. During the revision of the Carboniferous area round the city, Dr. Peach recently detected minute fragments of fishes in this sandstone where it is exposed at the side of the Queen's Drive. These were examined by Dr. Traquair, who considered them to be fragments of dendrodont (Holoptychian) teeth, though not specifically determinable. Permission having been granted by H.M. Office of Works in Scotland to charge the rock exposure with dynamite, a mass of material was set free, which, when broken up by the fossil collectors, Messrs. MacConochie and Tait, yielded conclusive fossil evidence. After examination Dr. Traquair determined a number of specimens of teeth and scales which undoubtedly belong to the genus ***Holoptychius,*** a characteristic Upper Old Red Sandstone form. Accepting this determination, it is obvious that the cementstones to the west must be faulted down against the Upper Old Red Sandstone of Salisbury Crags.

Attention was next directed to the Craigmillar sandstones lying to the north of Arthur's Seat, and hitherto grouped with the Carboniferous formation by the Geological Survey. Mr. Tait here obtained a number of very fragmentary fish-remains, one of which, according to Dr. Traquair, is an unmistakable fragment of a scale of ***Holoptychius.*** There can be no doubt, therefore, that the Craigmillar sandstones are also of Upper Old Red Sandstone age. At Raeburn's Brewery, not far from Duddingston Station, they are overlaid by dark shales and sandstones, with a thin coaly seam full of plant remains of Carboniferous type.

Thereafter a special examination was made of the sections north and south of the Warklaw Hill, four miles south-west of Edinburgh, which is formed of Lower Old Red Sandstone volcanic rocks, where conglomerates, pebbly sandstones and cornstones rest unconformably on that platform, and are overlaid by the Cementstone group. After careful searching by Mr. Tait, fish fragments were found which Dr.

Traquair considers fragmentary and indecisive. No undoubted Holoptychian remains were obtained. Those that have recognisable affinities are of *Dipnoi* and *Rhizodontidæ*, and might be either of Upper Old Red or Carboniferous age. Notwithstanding the indefinite fossil evidence, it is highly probable that the conglomerates, pebbly grits, and cornstones of Clubbiedean and Torduff are the equivalents of the sandstones and grits of Craigmillar and Salisbury Crags.

This discovery seems to us of special interest and importance, because (1) it is the first record of undoubted Upper Old Red Sandstone fish remains in the Edinburgh district; (2) it defines more precisely the area occupied by this formation round the city—a point of practical importance, as these sandstones are the source of the water supply for the local brewing industry; (3) it raises the question whether the base-line of the Carboniferous system throughout Scotland should not be drawn where the Ballagan type of the Cementstone group first appears.

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3. *Note on the Fish-remains recently collected by the Geological Survey of Scotland at Salisbury Crags, Craigmillar, Clubbiedean Reservoir, and Torduff Reservoir, in the Edinburgh District. By* Dr. R. H. TRAQUAIR, *F.R.S.*

The fish-remains from the sandstones of all these localities are very fragmentary, but from the Salisbury Crags sandstone portions of teeth of dendrodont, that is, Holoptychian fishes, are distinctly recognisable, and a piece of a scale was referable to *Holoptychius nobilissimus*, a characteristic Upper Old Red Sandstone fish. Among the fish-remains from Craigmillar, a portion of a scale also with the sculpture of *Holoptychius nobilissimus* has been found.

The remains from Clubbiedean and Torduff Reservoirs are still more fragmentary, and of the fragments none distinctly referable to *Holoptychius* have been as yet detected. Fragments referable to Rhizodont and Dipnoan fishes are present, but not generically or specifically identifiable, and it is therefore impossible to say whether they are of Upper Old Red or of Carboniferous age.

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4. *On the Fauna of the Upper Old Red Sandstone of the Moray Firth Area. By* Dr. R. H. TRAQUAIR, *F.R.S.*

The fish fauna of the Upper Old Red Sandstone of Britain is better developed in the Moray Firth area than in any other. There are twenty-two determinable species, of which four are noted in this paper as new. Of the genera, the most noteworthy and characteristic are *Psammosteus, Asterolepis, Bothriolepis,* and *Holoptychius.*

In this region we have evidence of three successive zones of fish life in the Upper Old Red—

1. That of the Nairn sandstone, being apparently the lowest, and characterised by *Psammosteus tesselatus, Asterolepis maxima,* and *Holoptychius decoratus.*

2. That of the Alves beds, including the well-known Scat Craig deposit, and characterised by *Psammosteus Taylori, Bothriolepis major,* and *Sauripterus crassidens. Holoptychius giganteus* and *H. nobilissimus* are also common.

3. That of the Rosebrae beds, apparently the highest of the Upper Old Red of the district. *Holoptychius giganteus* and *H. nobilissimus* are equally common in these sandstones and in the underlying Alves beds. *Bothriolepis major* is also found, but of comparatively small size, but there is a complete absence of the genus *Psammosteus.* The presence of *Phyllolepis concentrica, Glyptopomus minor,* and *Phaneropleuron Andersoni* furnishes, however, an interesting correlation with the uppermost Old Red beds of Dura Den, in Fifeshire.

The author expressed his great indebtedness to Mr. W. Taylor, of Lhanbryde, near Elgin, for furnishing him with most valuable material for prosecuting these researches into the fauna of the Upper Old Red Sandstone of the North of Scotland.

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5. *Note on Lower Cretaceous Phosphatic Beds and their Fauna.* *By* G. W. LAMPLUGH.

It has been customary to regard the fossils more or less imperfectly preserved in the condition of phosphatic casts in different parts of the English Lower Cretaceous series as derivative from the Jurassic rocks. In previous papers the writer has brought forward evidence to show that the fauna of such beds at Speeton and in Lincolnshire is not derivative, but occurs at its proper horizon and, so far as it goes, indicates the life of the period. Personal investigation of the localities, and of the fossils obtained from the 'coprolite beds' at Upware, Potton, and Brickhill, has led him to conclude that in these deposits also the greater part of the so-called derivatives are really of Lower Cretaceous age. Thus one of the most abundant phosphatic fossils of these places is the ammonite, usually fragmentary, which has habitually been named *Amm. biplex*, but belongs in almost every case to one or another of several allied species of Lower Cretaceous Olcostephani. Most of the lamellibranchs can likewise be best matched by Lower Cretaceous forms; and there are good grounds for suspecting that many of the saurian- and fish-remains from the above-mentioned places and from the Faringdon 'Sponge Gravels,' which have been classed as Jurassic, are true Lower Cretaceous forms.

It is acknowledged that the presence of transported pebbles of older rocks in the deposits at Upware, Potton, and Faringdon renders the occurrence of derivative fossils at these places more probable than in the case of the Speeton and Lincolnshire 'coprolite beds'; and in the collections examined a few specimens were noticed that seem to have been washed from older rocks. But the writer believes that these instances are exceptional, and he urges that no fossil should be set down as derivative unless the evidence is conclusive, as much confusion has arisen through the unquestioning adoption of the hypothesis of derivation.

While there is still much to be learnt as to the physical conditions requisite for the concretion of phosphatic nodules and for their segregation into bands, it seems clear that an important determinative was the existence of submarine currents occasionally impinging upon the sea-floor with sufficient strength to sweep away the matrix in which the nodules had been formed, so that there was a gradual accumulation of the partially eroded nodular residues. Such residues, though of inconsiderable thickness, may represent a long period of submarine conditions. The term 'aggregate deposits' has been suggested by J. F. Blake for beds of this character.

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6. *On Marine Fossils from the Ironstone of Shotover Hill, near Oxford.* *By* G. W. LAMPLUGH.

(*Communicated by permission of the Director of the Geological Survey.*)

The presence of casts of marine fossils, including *Trigonia*, *Perna*, and *Modiola*, in an ironstone rock on Shotover Hill resembling in appearance that which contains the Lower Cretaceous freshwater fossils, *Unio*, *Cyrena*, and *Paludina*, has long been known, but the horizon at which these marine fossils occur has not hitherto been ascertained. The writer found that these marine forms occur at the base of the Ironsand series, in a rock which appears originally to have been a sandy limestone, now converted, sometimes wholly and sometimes partly, into an ironstone by the replacement of the lime by iron. In other parts of the outcrop the limestone has been silicified, and the fossils are then almost entirely obliterated. From its position and fossils it is concluded that this rock belongs to the Portlandian series, and represents a portion of the Upper Portland stone, converted to its present state through the infiltration of ferruginous waters from the overlying ironsands.

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7. *On the Fossil Plants of the Upper Culm Measures of Devon.* *By* E. A. NEWELL ARBER, *M.A.*

The Upper Culm Measures form by far the largest portion of the Carboniferous sequence in Devon and the adjacent counties. Fossil plant remains are abundant in these beds, but their preservation is rarely sufficiently good to permit of even generic determination. A number of well-preserved specimens have, however, recently been obtained from the one horizon in which coal or 'culm' occurs in these beds in the Bideford district. They include *Calamites undulatus, Calamocladus charæformis, Alethopteris lonchitica, A. Serli, Neuropteris obliqua, Sigillaria tessellata,* and many others. *Neuropteris Schlehani* and *Megalopteris* (?) sp. are also recorded from Britain for the first time.

This flora confirms the previous conclusions with regard to the Upper Carboniferous age of these beds, and indicates that the coal-bearing beds of the Bideford district are the equivalents of the Middle Coal Measures elsewhere in Britain—a higher horizon than has previously been assigned to these beds.

8. *On Derived Plant Petrifactions from Devonshire.* *By* E. A. NEWELL ARBER, *M.A.*

Some interesting plant petrifactions in which the structure has been to some extent preserved by means of a mineral agent have recently been discovered in the higher beds of the Upper Culm Measures (Upper Carboniferous) in Western Devon. Although the preservation is not sufficiently good to render this discovery of any botanical importance, the manner in which the fossils occur is interesting from a geological point of view. The plant remains consist of small rolled fragments of stems, of an inch or less in length, arranged without order in a fine-grained sandstone. They are in all probability derived from some preexisting beds, and are not contemporaneous with the sandstone in which they are found. Such derived plant remains are very rare, if not unknown, from the Palæozoic rocks.

9. *Report on the Fauna and Flora of the Trias of the British Isles.* See Reports, p. 275.

10. *On Footprints of Small Fossil Reptiles from the Upper Karroo Rocks of Cape Colony.* *By* Professor H. G. SEELEY, *F.R.S.*

The author recognised a slab of fine-grained sandstone in the Palæontological collection of the University of Munich, which contains impressions of the feet of three kinds of reptiles and also preserves casts of small phalangeal bones terminated by compressed claws. This was collected about 1880, near Middleburg, together with a small Theriodont skull allied to Hyorhynchus.

The surface of the slab appears to show faint ripple marks, an inch or two apart. The larger footprints cross these markings at an angle of about 45°. The prints are in relief; indicate a pentadactylate animal, with the fore and hind feet of nearly equal size. The digits are widely spread, stout, and terminate bluntly, without any indication of claws. The palmar surface is most convex towards the first digit, and there is a convexity under each metacarpal and metatarsal bone. The point is less deep towards the outer side, so that the outermost digit appears to be exceptionally slender. The width of the hand is about one inch, and the length did not exceed one inch and a half; at the carpal border the width is eight-tenths of an inch. There appear to be four bones in the distal-tarsal row.

The hinder tarsal border is formed of three convex curves, which appear to indicate the three bones in the proximal tarsal row. There is a slight impression of the tail, showing a fine granular skin ornament, arranged quincuncially. In size the digits are not unlike those of Mesosaurus, though in the shorter

metapodial bones they are more like Procolophon. Their generic relation is not determined.

Two other animals of smaller size are indicated on the same slab. Both have the digits parallel, and apparently four in number, like some from the Trias of Cheshire.

A cast of this slab was made by the late Professor v. Zittel, and given to the author for description and presentation to the British Museum.

This is the first record of footprints in the Karroo rocks.

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11. *Report on Life Zones in the British Carboniferous Rocks.*—See Reports, p. 226.

MONDAY, AUGUST 22.

The following Papers were read:—

1. *Discussion on the Nature and Origin of Earth Movements.*

i. *Introduction. By* AUBREY STRAHAN, *M.A., F.R.S.*

The subject proposed for discussion is the nature and origin of those movements of the earth's crust which have manifested themselves in the fracturing, overthrusting, and folding of strata. These movements have been in operation from the earliest to the latest geological periods; and, though they have been intermittent so far as any one region is concerned, there is reason to believe that they have been more or less continuously in action throughout the world as a whole. Their operation, in fact, is essential to the existence of a land surface, for in their absence all rocks projecting above the sea would be worn away, and the globe would become enveloped in one continuous ocean.

Notwithstanding these facts, and though they have been the object of prolonged study, no theory as to the cause of the movements has commanded universal acceptance. Without attempting to enter in detail into the various theories which have been advanced, I will merely point out, for the purposes of the present discussion, that, while some hold that the shrinking of the globe by cooling and the efforts of the crust to adapt itself to the shrinking interior are the prime causes, others maintain that the scale on which folding and overthrusting in the crust have taken place is out of all proportion to the shrinking that can be attributed to such a cause.

Earth movements may be divided into two principal classes—namely, movements of expansion, which are evidenced in normal faulting; and movements of compression, such as are indicated by the buckling, overthrusting, and shearing of strata, by the superinduced structures of cleavage and schistosity, and by the extrusion of granitic rocks and metamorphism. All these phenomena have been made the subject of special study, and I believe that no better opportunity could be found than a meeting of this Section for comparing the views of specialists upon them, and for ascertaining how far those views point to a general agreement as to the causes of the earth movements upon which these phenomena are attendant.

ii. *Contribution by* Dr. JOHN HORNE, *F.R.S.*

The Earth Movements in the North-West Highlands.

The nature of the earth movements in the North-West Highlands in post-Cambrian time was illustrated by a series of horizontal sections across the belt of complication, that stretches from the north coast of Sutherland to Sleat, in Skye.

It was shown that, though the sections vary indefinitely along this belt, there are certain features characteristic of different stages of the movements which constitute well-marked types.

In the strip that generally intervenes between the undisturbed area to the west and the powerful thrusts to the east, the geological structures may be arranged in two groups: 1. The strata are thrown into a series of inverted folds accompanied by reversed faults or thrusts, which dip in one general direction towards the E.S.E.; this type is well represented in the region of Eriboll and in the mountainous district south of Loch Maree. 2. Without incipient folding, the strata are repeated by a series of minor thrusts or reversed faults which lie at an oblique angle to the major thrust-planes, and dip in the direction from which the pressure came—that is, from the E.S.E. This type is admirably displayed in Glen Coul, in Glen Dhu, and on the hill slopes N.N.W. of Inchnadamph, in Sutherlandshire.

It sometimes happens, however, that the structures characteristic of this stage of the movements are buried underneath the materials driven westwards by the powerful thrusts; but wherever denudation has laid bare the reduplication of the strata in advance of the great displacements, these structures are found.

The features characteristic of the more powerful thrusts may also be arranged in two groups. In the first, masses of Lewisian gneiss, Torridon sandstone, and Cambrian rocks are made to override the underlying piled-up strata, and in some cases to overlap other thrusts to the west. Owing to the movements of the strata from east to west, and also to the friction along the plane of the thrust, the strata fold over and curve under the Lewisian gneiss, thus producing inversion of the beds. These features are exemplified in the Eriboll region, in Assynt, and in the Loch Maree district, by the Arnabol, Glen Coul, Ben More, and Kishorn Thrusts. The materials brought forward by these displacements can be referred to different types of Lewisian gneiss occurring to the west, and to the respective sub-divisions of the Torridonian and Cambrian systems.

In the second group, which is represented solely by the Moine Thrust, the Eastern Schists, composed of quartz-schists, mica-schists, and muscovite-biotite schists, with lenticular masses of acid and basic gneisses of Archæan type, are driven westwards, and in some cases overlap all major and minor thrusts till they rest directly on the comparatively undisturbed Cambrian strata.

The planes of the major or powerful thrusts along which the materials have been driven are usually inclined to the E.S.E. at low angles, but in some cases they are folded, and, more rarely, are almost vertical.

One of the distinctive features of the major thrust-planes is, that their outcrops resemble the boundary lines between unconformable formations, because (1) there is a complete discordance between the strata lying above and below the planes of disruption; (2) each successive thrust may be overlapped in turn by the higher one. By means of denudation, outliers of the materials lying above the thrust-planes are formed, of which excellent examples occur near Inchnadamph, in Assynt, and to the south of Loch Maree.

iii. *Contribution by* J. J. H. Teall, *M.A., F.R.S.*

Effects of Earth Movements on Rocks.

The effects of earth movements on rocks may be either local or regional. Local effects are confined to the immediate neighbourhood of dislocations; regional effects are observable over areas that may be measured in tens, hundreds, or even thousands of square miles.

Fault-breccias and mylonites may be cited as well-known examples of local effects, the former being especially characteristic of normal faults and the latter of thrust-planes. In the majority of cases fault-breccias and mylonites are formed at the expense of the adjacent rocks, but this is not always the case. Vein-stones have not infrequently been deposited in cracks and fissures along which movement has taken place. Some of the tin lodes of Cornwall, for example, give evidence of

two or more periods of infiltration, followed by movements which have broken up the previously deposited material, consisting of quartz, tourmaline, and tinstone.

In the cases above referred to the evidence of the mechanical fracture of the rocks and of their constituent minerals is obvious, but in those which have now to be considered such evidence is rare or altogether absent.

The Lewisian gneiss of Scotland is traversed by a large number of basic dykes. Both gneiss and dykes are crossed by shear-zones in which the rocks have been deformed and in which the structure and, to some extent, the mineralogical composition of the original rocks have been changed. The basic dykes have become hornblende schists and the gneiss a hornblende granulite. Both rocks are now in the condition of holocrystalline schists, and although traces of mechanical fracture may sometimes be seen in the transitional forms, they are as a rule conspicuous by their absence, and are not found in the finished product.

The essential difference between fault-breccias and mylonites, on the one hand, and the holocrystalline schists of the shear-zones on the other, is that evidence of mechanical fracture, both of the rocks and of their mineral constituents, is abundant in the former and rare or absent in the latter. This difference is probably due to the fact that the deformation in the case of the shear-zones took place under a greater load and at a higher temperature.

The breadth of many of the typical shear-zones is only a few yards, but wider belts of country composed of similar rocks—hornblende schists and granulitic gneisses—occur, so that the consideration of these shear-zones helps to bridge over the gap between the two classes of effects—the local and the regional.

Regional effects are well illustrated by the phenomena of slaty cleavage, which is due to the mechanical deformation of extensive tracts of country. Sharpe and Darwin associated the foliation of crystalline schists with slaty cleavage, an association which appears to be justifiable, although the case as stated by them requires some modification. Much remains to be done before the problem of the origin of the crystalline schists is solved, but a few points of considerable importance have been definitely established.

Taking the Highlands of Scotland as an example, the foliated crystalline rocks of that region are, as a rule, easily separable into two distinct classes—those of igneous and those of sedimentary origin.[1]

In dealing with foliated igneous rocks there is, in many cases, a doubt as to whether the foliation may not date from the time of intrusion and be of the nature of original fluxion; but when a granitic mass, its apophyses and the metamorphosed sediments on its margin have a common foliation, and the apophyses are foliated transversely to their width, and not parallel to their margins, we are compelled to assume that the foliation has been produced by earth movements operating after intrusion, consolidation, and contact-metamorphism. This is the case, for example, with the Carn Chivinneag mass in Eastern Ross, which has recently been investigated by Mr. Clough.

Crystalline schists of sedimentary origin also form large tracts in the Highlands. They probably belong to more than one formation, and certainly include representatives of arenaceous, argillaceous, and calcareous types. To what extent the present condition of these crystalline schists is to be attributed to earth movements is more or less an open question. That they have been powerfully affected by such movements is often clearly proved by their disposition, by the presence of recognisable folds, and by the flattening or elongation of the clastic grains and pebbles in the coarser-grained sediments. If foliation be taken to include both parallel banding and the disposition of minerals with their longer axes in one definite direction, it is probable that in general the former is evidence of original stratification, although the thickness of a band, as we now see it, may be different from its original thickness, and the latter is the result of earth movement.

It appears, therefore, that the secondary foliation of igneous rocks and a part

[1] There is also a third class of mixed rocks, due to the impregnation of sedimentary with igneous material, but this class is relatively unimportant.

of the foliation of the crystalline schists of sedimentary origin must be attributed to earth movements and associated with the phenomena of slaty cleavage.

The Rev. OSMOND FISHER made the following communication:—

I used to think that the corrugations of the earth's crust were due to compression through the shrinking of the interior. To judge of the sufficiency of this cause the first thing to be done is to seek a measure of the compression, and then to compare the result of the effects of cooling with the actual amount of compression. The most satisfactory measure appears to be the thickness of the layer which the corrugations would form if levelled down. The question then becomes a question of *how much*. In 1863 Lord Kelvin (then Sir W. Thomson) formulated a law of secular cooling upon the hypothesis that the interior is solid. Adopting a probable value for the contraction of rocks in cooling, I calculated the thickness of the layer which would be produced by the corrugations resulting, and found it far short of that which the existing inequalities would form if levelled down. Mr. Mellard Reade and Dr. Davison subsequently discovered the existence of a level of no strain within the crust, and this greatly reduces the possible amount of corrugations. The conclusion at which I arrived was that, on the hypothesis of a solid globe, secular contraction through cooling would not account for the corrugations.

Numerous phenomena suggest to the vulcanologist that the substratum is a liquid magma holding water-gas in solution. The free yielding of the substratum is also testified by the phenomena of isostacy. I have therefore endeavoured to estimate the amount of corrugations which would be produced by a cooling globe also on this hypothesis. But although they would be slightly greater than in the case of a solid globe, they still fall far short of those actually existing. I therefore argue that the corrugations of the crust are not due to the shrinking of the interior away from the cooled crust, whether we regard the interior as solid or liquid.

My own view of this vexed question, which is based on the considerations given below, is that the substratum is affected by convection currents, and that these ascend beneath the oceans, and flowing horizontally towards and beneath the continents, and descending beneath mountain chains, are the cause of the compression of the crust, and other disturbances, of which we are in search.

It is, in the first place, necessary to combat the dictum of leading physicists that the interior of the earth is solid. It has been asserted that unless the earth is extremely rigid bodily tides would be produced, and that there would be no rise and fall of the water relatively to the land. If the earth was a smooth spheroid, covered with a uniformly deep ocean, this would, no doubt, be true; but as matters stand the tides of short period are affected by local irregularities, known as the establishment of the port. If the substratum of the crust is liquid, isostacy requires large protuberances of its underside, which would cause irregularities in the tides in the magma analogous to those in the ocean; and unless these agree in time, in height, and in place with the water tides, the latter will not be obscured by them, and may even be augmented.

Of tides of long period the fortnightly is the most important, but I think I have shown in the Appendix to my 'Physics of the Earth's Crust' that it had not been proved by fifteen years of observation that any such tide existed,[1] which would be an argument in favour of the liquidity of the interior.

The peculiarities of the transmission of earthquake waves to great distances through the body of the earth have been appealed to as proving to all 'except some geologists' that the earth is solid.[2] The disturbance first arrives as a series of minute tremors. These have been considered to be waves of compression. They are soon followed by somewhat larger disturbances, which have been considered to be waves of distortion. Since waves of distortion could not be propagated in a liquid, it is maintained that the earth is hereby proved to be solid. In reply to this argument, I have shown that if a liquid magma holds gas

[1] Page 34.

[2] Darwin's *Tides*, p. 236.

in solution two types of waves will be propagated through it, with different velocities. Tremors will first arrive, due to the compressibility of the magma, and subsequently waves, caused by the extrusion of gaseous vesicles, due to the changes of pressure. If my argument is valid, that for solidity loses its force.[1]

I will now give my reasons for thinking that the substratum, if a liquid, is not a still liquid, but is affected by convection currents.

Availing myself of Sir Arthur Rücker's observed values of the melting-temperature and specific heat of Rowley rag, I have calculated that if the substratum of the crust be a still liquid, the thickness of the crust comes out 22 miles, and the corresponding time since it began to solidify about eight million years. This is a much shorter time than geologists would admit. This result proves that the substratum is not a still liquid, and must, therefore, be affected by convection currents, bringing up heat from below and delaying the thickening of the crust. The existence of convection currents being thus, as I submit, established, I will add my reason for believing that they ascend beneath the oceans.

By a somewhat complicated calculation, which, although assailed by Mr. Blake,[2] has been ably defended by Mr. Brill,[3] I have, I think, proved that the substratum beneath the ocean is less dense than beneath the land. This shows that the upward currents are beneath the ocean. I have at the same time proved that the sub-oceanic crust does not reach quite so deep down as the continental crust, and that its upper layer is thin and very dense; from which I infer that it consists of basic lava flows, the oxydation of which would afford the red clay which covers the bottom of the deeper oceans.

These convection currents, ascending beneath the ocean, and then flowing horizontally towards and beneath the continents till they descend, are, in my opinion, the cause of the compression of the continental crust.

At the request of the President, Professor T. McKenny Hughes explained the position and arrangement of the specimens exhibited in the museum in illustration of the subject under discussion.

They were, as far as possible, arranged to show the 'nature' of earth movement and the relation between superinduced structures, which might suggest their 'origin.' Great continental folds, and local readjustments in connection with them, may be exemplified even in small specimens. From these we should infer, as we should also from observations over large areas, that faults and folds were generally due to movements in relief of lateral pressure, while faults due to the dropping of the marginal portion of uplifted and exposed areas are comparatively rare. What the nature of the movement will be in various regions would largely depend upon the character of the rocks affected. Heim had estimated the probable breadth of the Alps if the strata were pulled out flat. Similar calculations had been made among the folded mountain ranges of America; but, as our specimens show, all rocks were not susceptible of the same kind of compression. One rock had gained in vertical thickness at the expense of horizontal extension by molecular rearrangement of the particles, which had, or could assume, a flattened form at right angles to the direction of the pressure. Another rock which would not yield to this kind of readjustment must fold; but faults and crumplings occur along belts, and are in easement or relief of strain along lines of less resistance during movements of uplift and depression.

In the production of folding without fracture time is an element, and temperature must be taken into account. When the rocks do break, earthquakes record the rent, and volcanic phenomena follow the relief of pressure on the superheated rocks. If we could explain the great epeirogenic movements by a shrinking of the interior and a tangential pinching of the hardened outside crust, we should establish a *vera causa* which would involve the crumplings along limited belts, where vertical expansion was produced in compensation for horizontal extension. Nature is full of automatic compensations and conflicting forces, and in this dis-

[1] *Proceedings of Cambridge Phil. Soc.*, vol. xii., 1904.

[2] *Phil. Mag.*, 1894.

[3] *Phil. Mag.*, 1895.

cussion we must not forget the transference of large portions of the earth's crust from one region to another. Fifteen thousand feet of rocky material taken off a continent and thrown down on its margin must produce an appreciable disturbance, as we see on a small scale when a solid stratum is removed from above a shale or a mountain side, in a tunnel or in a quarry. The removal of blankets of sediment from one area and the heaping on of corresponding layers elsewhere must affect the transmission of heat and its many consequences. We must remember the different volume of rocks in a molten and solid state, and the tremendous power of crystallisation and chemical reactions. We must be careful not to think that we can explain the working of a clock when we have given a numerical estimate of the strength of the spring, without taking account of the controlling influence of the pendulum.

Professor SOLLAS remarked that Mr. Horne in his closing words had suggested the question which was most open to discussion, *i.e.*, How far could the hypothesis of a cooling globe be shown to explain the phenomena of disturbance in the superficial structure of the earth's crust? It was difficult to enter upon this inquiry without making some assumption as to the internal state and constitution of our planet. Professor Arrhenius regarded the interior as consisting of gas at a temperature above its critical point, but under a pressure which rendered it highly incompressible. Such a conception would afford the geologist a general contraction sufficient to meet all his needs. The Rev. O. Fisher, as the result of his investigations, had been led to regard the interior as fluid, but thought that even so the contraction resulting from cooling would be inadequate to account for the inequalities of the surface. While Mr. Davison, reasoning from Lord Kelvin's hypothesis of a solid earth, was led to an opposite result. But however authorities might differ as to the amount, none would deny that some contraction would follow from the secular cooling of the globe, and it was of interest to inquire by what kind of machinery this would act to produce mountain folds, with their associated thrust-planes and volcanic and seismic disturbances. It must be carefully borne in mind that folding is confined to comparatively narrow belts of the earth's surface, extensive masses of sediment remaining comparatively undisturbed in approximately horizontal platforms; that these belts occur near the margin, or the once existent margin, of the ocean, and that they are comparatively superficial, the causes which gave rise to them being deeper seated. If we consider the relative level of the continents and ocean-floor, we find the latter lies at an average depth of some two miles below the former, yet the continents appeared to be self-supporting. Wherever great folded ranges are in existence, however, we have evidence of a previous slow subsidence of the sea-floor bordering the land, a subsidence which, with lapse of time, had in many cases amounted to five or six miles. When the present difference in level between continent and ocean-floor had undergone so great an increase as this, it was doubtful whether the continent would continue to sustain itself, and if it gave way it would slide towards the ocean. Consideration of the distribution of pressure and isogeotherms below the crust suggested the possible existence of a zone of solid material near its critical fusion point, the slope of which might be seawards, and might lead to the formation of gently inclined glide planes. The movement of the continental mass would then give rise to compression, folding, and overthrusting of the marginal sediments, as well as accompanying seismic and volcanic action. The limited distribution of folded belts could be thus accounted for; but it might still be urged that the contraction due to cooling was inadequate to explain the subsidence on which this theory was based. There was, however, another cause to which attention might be directed, viz., a slow deformation accompanying a loss of rotational velocity. Mr. Jeans had shown that the original form of the earth, subsequent to the origin of the moon, was probably pear-shaped, and this figure, of which some vestiges still remain, would determine the primitive distribution of land and sea. As rotational velocity diminished, the form would approximate more and more to that of an oblate spheroid, and the oblate spheroid would become more spherical; in the course of these changes the Pacific belt of continents would be produced, and the

mountain ranges of the ancient Thetis. Contraction and this deformation acting together might be found to supply the explanation required. A decisive solution, however, could hardly be looked for at present; many physical data, especially the value of the coefficient of expansion for solid bodies near their critical fusion point, were not sufficiently known, and great authorities were ranged on opposite sides; at the same time, investigators like Joly and Barus were making important additions to our knowledge, and further advances might be hopefully looked for in the near future.

Professor J. F. BLAKE considered it more important to determine, in the first instance, the proximate causes of earth movements rather than the ultimate causes, which must be more or less speculative. Thus the thrust-planes of the N.-W. Highlands had inclinations pretty uniformly bringing upwards the overthrust materials, only the small minor thrusts bending down towards the end, as though they were locally stopped in their motion. This motion was from the east, where there existed a broad area of crystalline rock. These indications suggested the former existence of a mountainous region in this direction, which had afterwards sunk by its own weight and forced out the strata to the west, carrying with it portions of its own base, the yielding of which was the immediate cause of the motion. This, however, involved no important folding, and thus supported rather the ideas of Professor Rothpletz than those of Professor Heim. Folding, in fact, had, in the speaker's opinion, been much exaggerated; there was plenty of it, but too wide effects had been attributed to it. The speaker had never seen 'isoclinal' strata in the sense often implied, and never hoped to, for such folding was physically impossible, involving as it did the absolute destruction of the central layers. At most the structure might be called *plesioclinal*; and in this case the centre of the fold should always be somewhere recognisable, as it occurred throughout. If no indication could be found it argued that a fold was absent. There were also local causes of folding, of which an instance was quoted in the valley crossed by the excavation for dams made in carrying out the Derwent Valley water-scheme. Here the two sides of the valley showed uniform horizontal strata in the bedded Pendleside series; but where the stream was crossed a sharp uplift on both sides was seen in the section, while the underlying strata were said to be still undisturbed; thus indicating that the cause of the uplift originated at the stream, and was probably the relief from local pressure due to the excavation of the valley, and might be called, therefore, a kind of *earth-creep*.

Professor A. ROTHPLETZ said: I have had much pleasure in listening to the clear exposition that Mr. Horne has given us of the overthrusts and earth-crush movements in the Scottish Highlands, and in seeing the great importance given to these subjects by this meeting. It is more than twenty-five years ago that I had the first opportunity of studying an overthrust. At that time nobody cared for such things, and the text-books of geology hardly recognised the word at all.

The next overthrust I found in the Alps twenty years ago, but I had to defend it against almost everyone. So you may understand my delight when I came to the meeting of this Association at Nottingham, and had the good fortune to find there those geologists who had worked out so carefully the overthrusts of the Highlands, and to accompany them into that district.

But now opinions have changed so entirely that nobody in this room will be found to deny the existence of overthrusts.

Although I have now worked twenty-five years at the subject I am still very doubtful about overthrusts, because we do not yet know many of their essential features. How, for instance, do these wide and long overthrust-planes come to an end laterally? That we cannot see in the Highlands; but in the Alps I have found two great overthrust-planes which strike from S. to N. at a place where the strike of the folds is E. to W. So the shortening in one direction took place by folding, while the shortening in a direction at right angles to that was by overthrust. Following those overthrust-planes to the north and south, we see that before reaching the boundaries of the Alps they simultaneously and suddenly turn eastward and lose their horizontal character. They become longitudinal and more or

less vertical fault-planes, which we may follow to the east end of the Alps. So they enclose an enormous mass of mountains, which have moved from E. to W. along these longitudinal fault-planes like a car on the rails.

Now, are the particular features of these Alpine overthrusts of general application? It may be so or not. Nothing but further field-work can clear up this point.

Of course the forces which made these overthrusts must have been enormous, and there is naturally a great tendency to attempt to calculate their origin.

Field geologists are not so well fitted for doing this, because they have too great a knowledge of detail, and are too much puzzled by what they have not yet fully elaborated. It is easier for those who are mainly occupied in working at theory and who are not disturbed by detail. They can more readily accept the simple assumptions which are wanted for mathematical analysis.

We have just seen, however, that in theory, too, there are many difficulties and much difference of opinion; and so I do not think that questions of the nature and origin of overthrusts will be solved so quickly as Professor Sollas hopes and anticipates.

Professor Boyd Dawkins called attention to the foldings and faults caused by the relaxation of pressure at the bottom of valleys carved out of the elastic shales and thin sandstones of the Yoredale and Millstone Grit rocks, which he had observed in the upper valleys of the Derwent and of the Don during the construction of reservoirs. The folded and faulted strata extend to a depth of from 40 to 120 feet from the surface, and rest on undisturbed shales and sandstones. They are due to the lateral pressure of the sides acting on the valley, from which the counterpoise of rock has been denuded away, and are analogous to the 'creeps' in coal-workings. We must, therefore, add the relaxation of pressure to the causes of folding and faulting recognised in geological theory.

Professor John Milne remarked that the number of worlds which had been invented by geologists, physicists, and others exceeded the number which they had heard about in their youth. New worlds had even been invented whilst he had been in the room, and to them he ventured to add another—a world that would meet the requirements of the seismologist. The world which they required was one which would convey earthquake waves with a velocity which was nearly uniform along chords corresponding to arcs greater than 30°. In other words, a fairly homogeneous nucleus was required, and this nucleus should have a 'rigidity' about twice that of steel. Such a world would not be far removed from the one suggested by Wiechert, which was in agreement with the requirements of astronomy and geodesy. In other respects it resembled the world of Arrhenius.

Professor Percy F. Kendall said that he had no intention of discussing the general question of the causes of earth movements, but merely desired to make one observation upon the remarks of Professor Sollas, who had pointed out that the continental margins were the seat of the most important mountain-making movements.

Upon the hypothesis that there was a critical zone at which temperature would impart a viscosity to rocks, he thought the sub-oceanic margins might, for another reason than that suggested by Professor Sollas, be the regions where the yielding of the crust would take place.

The accumulation of a great thickness of sediment, such as took place in proximity to coast-lines in a sinking area, would have the effect of producing a rise of the ge-isotherms and of the critical zone. If, then, a movement of accommodation were initiated, there would be above the critical zone a region of relative weakness, where the new-formed and imperfectly consolidated sediments constituted perhaps two or three miles of the superincumbent crust, while the continental mass would be relatively stiffer. The yielding and crumpling would, therefore, be localised in this belt.

2. *Evidence in the Secondary Rocks of Persistent Movement in the Charnian Range. By* Professor PERCY F. KENDALL.

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3. *River-capture in the Don System. By* Rev. W. LOWER CARTER, *M.A.*

The river Don has a remarkable semicircular course. Rising in the Middle Grits west of Dunford Bridge at 1,500 feet above O.D., it flows eastwards to Penistone (700′), where it makes a bend to the south-east, quickly deepens its valley to 500′, and at Wortley breaks through the great watershed (1,000′) of the Grenoside and Wharncliffe grits. It then receives the Little Don, the Ewden, and the Loxley, on its right bank, and falls into the valley of the Sheaf at Sheffield (150′). The Don then makes a rectangular bend to the north-east, following the old valley of the Sheaf to Conisborough, receiving the Rother on its right bank at Rotherham (87′) and the Dearne on its left bank at Denaby (45′). It then traverses the Magnesian Limestone escarpment in a fine gorge and continues past Doncaster in a north-easterly direction to Thorne, where it bends northwards towards the Aire, which it formerly entered at Snaith. It has, however, been artificially diverted by the Dutch river to the Ouse at Goole.

The history of the present river course is presumed to have commenced when the Pennine anticlinal rose from the Cretaceous sea, and the original consequent streams commenced to run down the dip-slope of the Chalk. Slack Beck (Broadstone Dyke), which is diverted south-east at Ingberchworth by a tributary of the Don, is considered to be the head-stream of the brook that runs by Cawthorne, only a narrow dip in the watershed dividing them. The Don at Penistone (700′) faces a watershed of 700 feet, which forms a dip between Hoyland Swaine (900′) and Thurgoland (810′). Immediately beyond this watershed are the head-waters of the Dove, flowing eastward in direct continuation of the course of the Don above Penistone. The Dove is thus considered to be the beheaded remnant of the Don. The southerly bend of the Don and the cutting of the Wharncliffe gorge are explained as due to river-capture by a feeder of the Sheaf. This Wharncliffe stream, with a rapid fall to the Sheaf, was able to capture successively the Loxley, the Ewden, and the Little Don, and then the watershed at Wortley was attacked by a branch of this stream, and on the other side by a feeder of the Don. As the watershed was cut through, the Wharncliffe stream, by reason of its steeper fall, captured the Wortley feeder of the Don and then the Don itself.

The Dearne.—At a very early date the Bretton stream must have been captured by the Darton feeder of the Cawthorne stream, as it flows straight at the Woolley Edge escarpment (527′), and therefore must have been captured before the land was reduced to this level. The Dearne flows eastwards, by Barnsley to Cudworth Common, where it makes a rectangular bend southwards, and cutting through the Upper Chevet Rock (225′) at Darfield, enters the old valley of the Dove (100′). This gorge at Darfield proves the extension of the 225-foot contour eastwards, towards Hickleton, forming the watershed between the Dearne and the Dove, and there is an old river valley at Frickley (200′) between Clayton and Hickleton, which was probably the original course of the Dearne, which flowed through Hampole gorge into the central plain. The Darfield gorge is a case of river-capture by a feeder of the Dove. The Dove itself had probably been captured by the Sheaf at a period before the present level of the Magnesian Limestone escarpment was reached by denudation.

The Rother.—The original consequents of the Rother are Shire Brook, the Moss, and the Staveley stream. The Shire and Moss probably coalesced and formed the head-waters of the Ryton. The two gorges (330′) uniting at Kiveton are plainly traceable, and have subsequently been used, in all probability, as a channel of glacial overflow. The Moss must have captured the Staveley stream before it was itself captured by the Rother.

The whole inner Don system is thus explainable by a series of river-captures,

due to the deep cutting of its valley by the Sheaf, and its resulting predominant power in capturing consequent streams north and south.

The northward bend of the Don, after its entrance into the central plain, is due to river-capture by a feeder of the Aire. The course of the old Don river from Thorne, along the north side of Hatfield Chase to Adlingfleet, on the Trent, is clearly traceable, and may have been one of the previous channels of the whole river.

4. *On the Elephant Trench at Dewlish, Dorset: Was it a Pitfall?* *By* Rev. O. Fisher, *M.A.*

The author refers to papers upon the trench at Dewlish, by the late Mr. Mansel-Pleydell,[1] Mr. Clement Reid,[2] and himself.[3] After describing the course of the excavations made by Mr. Pleydell in 1889, he points out the apparent impossibility of accounting for the formation of such a trench by natural agency, and for its containing the remains of so many elephants. He then refers to the present practice of taking elephants in pitfalls by the natives of Africa, and suggests that the trench at Dewlish was artificially dug for a similar purpose.

The species of elephant found here being *E. meridionalis*, the author refers to flints, considered to have been worked, being procured from the 'forest bed' of Cromer, where they are associated with this early species of elephant, and alludes briefly to some of the geological questions involved.

5. *Notes on the Glaciation of Holyhead Mountain.* *By* Edward Greenly.

The glaciation of Holyhead Mountain is of considerable interest on account of its position far out in the Irish Sea Basin. Its northern and eastern slopes are strongly rubbed and rounded, and striated in a general N.E.–S.W. direction, with local deflections. Striæ cross the very summit, 721 ft. above the sea, running S. 40° W. This direction agrees with that of the general glaciation of Anglesey.

A strong feature traverses the mountain from N. to S. facing W., and forms also the line of great sea cliffs near the North Stack. The edge of the crag is polished, and, in spite of being sheltered by a steep rocky brow rising some 50 or 100 ft. behind it to the east, is traversed by striæ from N.E. to S.W. Examples are also given of undercut furrows, and of glaciation of overhanging surfaces.

The mountain is very bare of drift, but a little till occurs in hollows. At the summit are abundant fragments of the green mica schists of the neighbourhood of the town, which do not occur *in situ* at a higher level than 200 or 220 ft. These have, therefore, been raised some 500 ft. above their source.

The phenomena, when all are considered, appear to the author to be ascribable, with probability, to land ice.

Finally, there are some ill-defined mounds, composed of local *débris*, which appear to be moraines, as if small local glaciers had gathered here for some time, in spite of the moderate elevation.

6. *Report on the Erratic Blocks of the British Isles.*—See Reports, p. 237

[1] *Proc. Dorset Nat. Hist. and Antiq. Field Club*, 1889, vii.; 1893, xiv.
[2] *Geol. Survey: Mem. on the Country round Dorchester*, 1899.
[3] *Q.J.G.S.*, 1888, xliv. 818.

TUESDAY, AUGUST 23.

The following Papers and Reports were read:—

1. *On the Origin of the Great Iron-ore Deposits of Lapland.* *By* Dr. HELGE BÄCKSTRÖM.

The great ore sheet of Kirunavara-Luossavara occurs between old lava streams and volcanic conglomerates, in other words between rocks formed by volcanic action at the surface. It seems to mark an interval between two separate eruptions or eruptive periods, as the rocks on both sides are different, although showing a distinct consanguinity. The ore bed is *older* than the overlying quartz porphyry, while at the same time it is *younger* than the underlying syenite porphyries. The underlying porphyries show characteristic evidence of a hydrochemical or pneumatolytic action, which has left no similar traces on the overlying porphyries, and must therefore have occurred in the interval during which the ore was formed.

From these facts we may presume that the magnetite-apatite sheet was formed by the volcanic activity which produced the overlying as well as the underlying rocks, and that the hydrochemical or pneumatolytic transformation of the underlying porphyries was effected by the same agents which brought the iron and phosphorus up to the surface of the earth.

The Ekströmsberg ore-field, situated about twenty miles west of Kirunavara, ranks as the third of the great Lapland iron mountains; the probable quantity of ore has been estimated by the author at one hundred million tons. The ore is partly magnetite, partly hæmatite, with 63 per cent. Fe, 1·25 per cent. P, on the average. The surrounding rock is a quartz porphyry, but with potash instead of soda as the dominant alkali, the same variety occurring on both sides of the ore sheet. In the ore-field of Mertainen, situated eighteen miles south-east of Kirunavara, the ore is magnetite without apatite, but the quantities of rich ore present are comparatively small, the principal part of the ore-field being occupied by ore breccias or mixtures of porphyritic and ore material. The original rock of the district is a syenite porphyry. In the ore-field this is penetrated by veins of magnetite with biotite, hornblende, and titanite. These minerals, and especially the magnetite, also occur, filling amygdules. This penetration of the original rock by magnetite in those places where it was most favourable for penetration, resulted in the formation of the ore breccias, in which the ore, so to say, has eaten away most of the porphyritic material. An intense transformation of the porphyry has gone on hand-in-hand with this infiltration of the ore material. Of the original phenocrysts of the dark minerals not even pseudomorphs are found; the biotite and hornblende present are of secondary formation. The plagioclase is very often partly transformed into biotite or titanite, but still more often into *scapolite*, which latter transformation is of very great interest when the transformation of plagioclase into scapolite along the apatite veins occurring in gabbros is remembered.

That the iron ore of Mertainen, occurring to a great extent as veins and ore breccias and accompanied by such transformations of the surrounding rock, should be of pneumatolytic origin, seems very probable. But the author thinks this theory must be adopted also for the great masses of Kirunavara-Luossavara and Ekströmsberg, closely connected as they are with volcanic rocks. Hence these iron-ore deposits have probably got their material from below through volcanic emanations belonging to the last phase of the volcanic activity (or to an interval in the activity, as in Kirunavara), emanations of iron, phosphorus, or titanium compounds, essentially chlorides and fluorides, in the form of gases or superheated solutions, which on reaching the surface regions were decomposed by the water and the silicates with which they came in contact.

This theory may appear rash, especially when applied to such enormous masses as the Kirunavara-Luossavara magnetite-apatite sheet, but it seems to the author to be only an extension of the generally accepted theory of the origin of the contact deposits. In both cases the material has come with the eruptive rock from

below, although in one case the ore has been deposited along the margins of an intrusive rock, and in the other case at the surface or in the regions near the surface.

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2. *Exhibition of Specimens of Tertiary Plutonic Rocks (including Gneisses) from the Isle of Rum. By* ALFRED HARKER, *M.A., F.R.S.*

(*By permission of the Director of the Geological Survey.*)

Of the plutonic rocks of Tertiary age, which make up about one half of Rum, the ultrabasic group is the most important. It includes various *peridotites*, some essentially of olivine, but others containing pyroxenes, and especially anorthite. A noteworthy amount of lime and alumina, giving rise to anorthite, is indeed a special characteristic of the group. Equally striking is a tendency to separation of the more peridotic and the more felspathic portions of the magma, usually with a stratiform disposition. With bands of true peridotite alternate others of *allivalite*, a rock consisting of anorthite (predominant) and olivine, and even containing seams of pure *anorthite rock*. Another peculiar type, styled *harrisite*, is composed essentially of olivine (predominant) and anorthite, the olivine occurring here as large lustrous black crystals, with good cleavage.

Later than all these rocks, and intruded beneath them, comes the *eucrite* group, which shows less variety. The rocks are usually somewhat rich in olivine; much of the pyroxene is hypersthene, and the felspar is near anorthite. Still later comes the *granite* group, mostly hornblendic and often with granophyric structures. The acid magma has entered into peculiarly intimate relations with the eucrite, not only metamorphosing and impregnating that rock, but enclosing and partially incorporating portions of it, large and small. The enclosed portions, in a half-digested state, have been streaked out by movement, and there has arisen a group of well-banded *gneisses*, closely resembling the Lewisian of the North-western Highlands. These Tertiary gneisses are all of the nature of hybrid and composite rocks, of which the contributing elements are the eucrite and the granite, and their genesis can be traced step by step in the field.

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3. *The Lava-Domes of the Eifel. By* EDWARD GREENLY.

Associated with those cones and craters of the Eifel which are so remarkably preserved, and have suffered so little from denudation, are many bosses and domes of massive igneous rock, particularly of phonolite. If these are the denuded necks or stumps of volcanoes, they must be far older than the cones and craters. It is suggested, however, that they may be really contemporaneous, and have originated in the same way as the recent lava-pyramid of Mt. Pelée. This suggestion is supported by considerations connected with the distribution of the Trass; and by comparison with some other domical and pyramidal masses.

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4. *Report on Geological Photographs.*—See Reports, p. 242.

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5. *Concretions as the Result of Crystallisation. By* Professor H. A. MIERS, *F.R.S.*

In the gold districts of the Urals decomposed crystals of iron pyrites are not uncommon, which when sawn in half are found to contain a nucleus of gold; fresh crystals from the same localities are auriferous, but have the gold uniformly distributed. Similar nuclei are found in decomposed aikinite (a sulpho-bismuthite of lead and copper) at Beresovsk, but here the nucleus of gold is, like the crystal of aikinite, rod-shaped. In both cases the metal has become concentrated during the decomposition of the mineral in which it was contained.

It is well known that crystallisation may result in a concentration of material, as when the small crystals in a solution become redissolved and reappear as a large crystal. That the concentrating agency in the case of the decomposed pyrites may have been crystallisation is suggested by the fact that the nucleus has crystal facets.

Other examples of the attractive force exerted during the growth of crystals are afforded by such things as gypsum growing in clay, where, as was pointed out by Bunsen, the force does work and thrusts up the clay, often in considerable masses. Again, Klocke found that an alum crystal during growth may raise itself in the solution.

If this attractive force exists it should also manifest itself in a concentration of the material in the neighbourhood of a growing crystal, and this the author has found to be the case. By means of total internal reflection he has determined the index of refraction, and hence the composition, of the solution in contact with growing crystals of alum and other substances, and has always found the solution to be supersaturated.

The author suggests that in cases where no other explanation is forthcoming a sufficient cause for concretionary growth may be found in the attractive action of growing crystals. Marcasite, hæmatite, barytes, and many other concretions, are really crystalline in structure; and Liversidge has shown that gold nuggets are always so.

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6. *Basic Patches in the Granite of Mount Sorrel, Leicestershire.* *By* R. H. Rastall, *B.A.*

Dark-coloured patches are very abundant, and may be divided into three types:—

(1) Small black or grey angular patches, without porphyritic felspars.
(2) Larger ovoid patches of a brown colour, with pink porphyritic felspars.
(3) Black patches showing banding and *lit-par-lit* injection by the granite.

Type (1) consists of felspars and hornblende with a little quartz. Small crystals of plagioclase and hornblende are enclosed in poecilitic fashion by large plates of orthoclase.

The second type is very similar microscopically, but quartz is more abundant. The large felspars are often much corroded.

Both types are almost free from biotite, although in the normal granite it is the dominant melanocratic mineral. There is abundant sphene, of a peculiar habit, often moulded on the felspars, with an approach to ophitic structure.

These patches show a great resemblance to many metamorphosed basic igneous rocks, and attention is called to the resemblance between them and the early stages of the alteration of the Scourie Dyke, described by Mr. Teall.[1] It is concluded that they are fragments of basic rocks caught up by the granite magma during intrusion.

A specimen of the banded type consists of brown biotite and magnetite, enclosed poecilitically by plates of perthite, microcline, or orthoclase. It is very like many metamorphosed slates, and is probably a fragment of a sedimentary rock. This type is rare.

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7. *On the Different Modifications of Zircon.* *By* L. J. Spencer, *M.A.*

Some very irregularly developed crystals of zircon from the gem-washings of the Balangoda district in Ceylon were found to have characters differing widely from those of zircons of more common occurrence. Although of low specific gravity (4·0), they are not increased in density when strongly ignited, as are many

[1] *Q.J.G.S.*, 1885, p. 133.

zircons of specific gravity below 4·7. They further differ from ordinary zircon in their very feeble, or absence of, birefringence. The crystals are dark brown in colour and almost opaque, but after ignition they are bright green and quite transparent.

While some of the crystals consist wholly of zircon of this type, others contain an intergrowth of a second kind, which may be present in greater or less amount. The latter has a higher specific gravity, and increases in density when ignited; it is optically biaxial with very strong birefringence. A section cut perpendicular to the principal axis of such a compound crystal shows, when moved across the microscope-stage in convergent polarised light, a gradual transition from a biaxial to a uniaxial figure, the coloured rings at the same time moving outwards and becoming further apart owing to the diminution in the strength of the double refraction, which is positive throughout; finally, when the rings have all moved out of the field of view, the black cross also disappears and the corresponding portion of the section is optically isotropic. The mean refractive index has about the same value in all portions of the section.

Zircon of the first type has been previously described by Professor A. H. Church (1875), and by Dr. S. Stevanović (1903), and from the researches of these and other authors it would seem that there are, at least, three modifications of zircon, viz.:—

a. Those of specific gravity 4·0, which do not increase in density when ignited.
β. Those of specific gravity 4·7, also not increased in density when ignited.
γ. An unstable form of specific gravity about 4·3, which when ignited is increased in density to 4·7.

That these different kinds are often intergrown in the same crystal is shown by the frequent occurrence of zonal structures in zircon, and further by the behaviour of the crystals when heated. A crystal consisting of an intergrowth of *a*-zircon and *γ*-zircon will be increased in density on ignition, but not to the higher limit of 4·7; on the other hand, an intergrowth of *β*-zircon and *γ*-zircon will reach the higher limit when ignited.

In crystalline form and chemical composition (as far as could be determined by qualitative tests), *a*-zircon and *β*-zircon are identical, and these appear to be also the same for *γ*-zircon.

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8. *A Preliminary Description of Three New Minerals and some Curious Crystals of Blende from the Lengenbach Quarry, Binnenthal. By* R. H. Solly, *M.A.*

The author dealt with three new minerals, whose composition has not yet been determined, for two of which he proposed the names Lengenbachite and Marrite. He also described crystals of blende having a brilliant grey metallic coating on their surfaces and resembling galena or tetrahedrite.

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9. *On the Granite from Gready, near Luxullian, in Cornwall, and its Inclusions. By* Professor Karl Busz.

In 1880 J. A. Phillips published in the 'Quarterly Journal of the Geological Society' a description of the granite from Gready, in the parish of Luxullian, in Cornwall, and the concretionary patches contained in it. This granite he describes as sometimes containing dark-coloured patches of irregular shape, firmly embedded in the rock, and exhibiting distinct and sharply defined outlines. On examination he found them to be composed of the same minerals as the enclosing granite, and consequently considered them to be abnormal arrangements of the minerals constituting the granite itself, and essentially consisting of a fine-grained variety of the granite in which they occur.

A few years ago I happened to visit the same locality. The granite is still

extensively worked in large quarries for building material, and on that account I was able to collect a number of suitable specimens for investigation.

The granite itself is of much interest on account of the presence of several constituents which rarely occur in this kind of rock. It exhibits on the whole a uniform medium-grained structure, but is in some parts porphyritically developed, and contains large well-defined crystals of white orthoclase; it is also traversed by pegmatitic veins, which contain much tourmaline and apatite, while mica disappears.

When examined under the microscope, thin sections of this granite are observed to be composed of the following constituents: Quartz, orthoclase, oligoclase, albite, white and brown mica, tourmaline, apatite, zircon, magnetite, fluorite, andalusite, cordierite, and chlorite—the last-named as a decomposition product. Further constituents, occurring only in cavities in the pegmatitic veins, are lepidolite and gilbertite. Quartz occurs in the usual form of grains or granular aggregates, and contains numerous liquid inclusions, some of them showing a crystal of salt.

The orthoclase is of a pure white colour; its phenocrysts are of considerable size, being sometimes about 4 inches long and 2½ inches wide. They are Carlsbad twins, and occasionally two such crystals form penetration twins of cruciform type, similar to the pseudomorphs of cassiterite after orthoclase, which are well known from Cornwall, the twinning plane being probably a face of the pyramid P ($\bar{1}11$). Under the microscope the orthoclase is seen to be more or less decomposed, passing into a kaolin-like substance. It contains a great number of inclusions: numerous flakes of black mica can be observed macroscopically, which generally accumulate in the centre of the crystals or are arranged in layers parallel to their faces. White mica also is very abundant, and occurs in micropoikilitic intergrowth with the orthoclase, forming sponge-like aggregates; there can be no question about this mica being a primary constituent and contemporaneous with the orthoclase in which it is embedded. Microperthitic intergrowth of orthoclase and albite is very common; and it may be mentioned here that albite frequently envelops the orthoclase crystals, which occur well crystallised in cavities of the rock.

There is also a fair amount of plagioclase present; its colour differs somewhat from that of orthoclase, being yellowish white. Under the microscope it exhibits, as a rule, a better state of preservation; the sections are perfectly transparent, and contain but few inclusions and alteration products. Twin lamellation is well marked, and the optical properties are those of oligoclase.

Brown and white mica both occur abundantly. The former contains numerous small crystals of zircon, which are always surrounded by pleochroic halos, whereas the white mica is almost free from inclusions. Parallel intergrowth of the two is very common; the brown mica is often seen to pass into green chlorite; the white mica is often twinned according to the common law; the composition plane being sometimes the twin plane itself, in which case a twinned flake shows different optical orientation in different parts of the basal plane, and the interference-figures appear disturbed.

It has been suggested that in tourmaline-bearing granite the tourmaline may have been produced through the action of vapours containing boric acid on mica, and that in this way it replaces the mica. It seems as though our granite confirms this view. Tourmaline is a never-failing constituent of the rock throughout, and although it does not occur very abundantly, yet one or more grains of it can be detected in every thin section. The pegmatitic veins of the granite, however, contain a great quantity of tourmaline, and it occurs in large crystals and crystalline aggregates of radiating structure; the prisms reach a length of 10–12 cm.; biotite and muscovite, on the other hand, are very rare. Of great interest is the parallel intergrowth of biotite and tourmaline; it sometimes appears as if the tourmaline intrudes into the mica, and the pleochroic halos surrounding the inclusions in the latter are sometimes half situated in the mica and half in tourmaline. This intergrowth has not been observed with tourmaline and the *white* mica. The colour of the tourmaline in thin section is brown, or seldom blue, both colours also appearing on the same crystal; zonal structure is very conspicuous in most crystals.

Apatite is very abundant, occurring in small crystals or grains in the ordinary granite, or in larger masses intergrown with tourmaline in the pegmatitic veins, and is here of a pale sky-blue colour. In many of the cavities it is well crystallised, and forms shining, perfectly transparent pale-blue crystals of a size up to ½ cm. diameter.

Very remarkable is the occurrence of andalusite and cordierite as constituents of this granite, both of them being rare. The former occurs in grains or aggregates of grains, which very distinctly exhibit the characteristic pleochroism of andalusite, pink and colourless. Cordierite may easily be taken for quartz, being colourless in thin sections, and exhibiting no distinct cleavage traces. There are, however, several characteristic properties, which also facilitate the identification of this mineral in the present case—firstly, the twinning, resulting through penetration of three individuals in the formation of a pseudo-hexagonal crystal; secondly, the pleochroic halos of yellow colour, which cannot occur in quartz; and, thirdly, the decomposition products, consisting of felty aggregates of micaceous or serpentine-like minerals. In some cases the crystals are entirely altered into decomposition products.

The concretionary patches contained in the granite consist of a fine-grained rock of black colour, and show quite irregular but sharply defined outlines. Numerous small shiny flakes on the fresh surface indicate that mica is a predominant constituent. Under the microscope the rock is seen to consist essentially of quartz, cordierite, and biotite; accessory constituents are a few crystals of magnetite and small crystals or grains of zircon, generally embedded in cordierite and surrounded by a pleochroic halo, which by its deep yellow colour contrasts very strongly with the colourless cordierite. There is no felspar of any kind, and the rock is precisely equivalent to the cordierite-hornfels known from many zones of contact with granite. It is therefore evident that these inclusions cannot be regarded as products of differentiation of the granitic magma, but as fragments of sedimentary rocks altered by the influence of the eruptive mass.

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10. *Report on the Movements of Underground Waters of North-west Yorkshire.*—See Reports, p. 225.

WEDNESDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *Exhibition of a Model of the Cleveland Area, showing Glacier Lakes. By* Professor PERCY F. KENDALL.

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2. *The Glaciation of the Don and Dearne Valleys. By* Rev. W. LOWER CARTER, *M.A.*

In studying the geological history of the rivers of the Don system, my attention was specially directed to the evidences of glacial action in the area, with the object of ascertaining whether glaciation had anything to do with the interesting diversions of the Don, Dearne, and Dove. Certain valleys in the area, also, attracted my attention as possessing abnormal features with respect to the present drainage of the district, and I began to inquire what their relations might be to an altered system of drainage during the Glacial Period. The present paper is an attempt to piece together the scattered glacial evidence, and to ascertain the effect that the advance of a glacier from the north and north-east would have on the drainage of this district, and how far the present valleys would help to explain the water-flow under such conditions.

i. *The Glacial Deposits of the Don System.*

These are fragmentary and scattered, and probably but relics of considerable deposits of drift. There are two considerable areas covered with true boulder clay in this district—one at Staincross, Carlton, and Royston, near Barnsley, and the other at Balby, near Doncaster—each filling a small valley which, since the Glacial Period, has been slightly removed from the line of direct drainage, and hence has escaped denudation.

The Staincross boulder clay, as described in the 'Memoir on the Yorkshire Coal Field,' consists of two beds of stiff unstratified till, separated by a thin seam of warp and sand, the lower containing only boulders of Carboniferous sandstone and limestone, chert, and a blue, close-grained trap. The upper bed is more sandy, and on the surface have been found many erratics, including a large shap granite (25 cwt.), Armboth felsite, Threlkeld quartz porphyry, andesitic ash, rhyolite, &c. These beds fill a hollow cut out of the Woolley Edge Rock; the junction is much shattered and smashed, and large blocks of the sandstone are embedded in the clay. The Yorkshire Boulder Committee report that the country to the north and east of this patch is covered with erratics, and similar boulder clays are found at Burton Grange, near Barnsley, and at Ardsley, on the opposite side of the river Dearne. Mr. Walter Hemingway, of Barnsley, has recently traced two tongues of this drift into the valley of the Dearne, and has recorded a section of contorted shale with pockets of erratics from the excavation for the Barnsley gasometer.

The Balby boulder clay occupies an area of about five acres in extent. It occupies part of a small valley in the Magnesian Limestone, which previously was filled with Bunter sandstone. In three large pits a magnificent section of 40 feet of stiff till is shown which has yielded many erratics, including a shap granite (2 cwt.), andesites and andesitic breccias, Eskdale granite, St. John's Vale quartz porphyry, Carboniferous limestone, chert, Millstone grit, &c. The Bunter sandstone on which this till is seen to rest has been scooped out to form a clean, level floor, without any sand or gravel intervening under the clay. In the excavations for the workhouse a section of this till showed masses of Bunter sandstone torn off and embedded in the till.

About halfway along the arc joining Staincross and Balby is another patch of boulder clay at Adwick-on-Dearne, containing Carboniferous sandstone, quartzite, felstone, and encrinital chert. Close to this patch was found a third boulder of shap granite (15 cwt.). Contiguous to this zone are several patches of gravel containing Carboniferous sandstone with quartzite and chert, and a boulder of ganister (of Leeds type) lies on the summit of Wombwell Hill.

Beyond and to the south of this zone are several scattered patches of drift. At Barbot Hall, about one mile north of Rotherham, is a little hill covered with clay containing pebbles of quartz, sandstone, Carboniferous limestone, and Oolitic rocks. At Masbrough sand and gravel are found containing pebbles of Carboniferous sandstone and quartz rock, and at Sitwell Vale, one and a quarter mile south of Rotherham, is a clay with pebbles and boulders of Carboniferous sandstone. Near Hooton Roberts are three or four patches of gravel containing Carboniferous sandstone, with quartz, quartzite, and black chert.

At the western entrance of the gorge of the Don, at Conisborough, a bed of boulder clay (about 15 feet thick) is shown at the Ashfield Brick Works (225 feet above O.D.), including Lake Country andesites, Carboniferous limestone, a talcose schist with garnets, and other rocks. About the same level, on the opposite side of the gorge, at Cadeby, is a patch of drift with Carboniferous limestone blocks. Mr. H. H. Corbett, of Doncaster, has also kindly told me of a section of boulder clay recently exposed in the valley between the railway station and Conisborough Castle. At Sprotborough and Cusworth, on the north side of the gorge of the Don, are patches of drifted sand and pebbles, and from the fields have been ploughed up small boulders of diorite, basalt, mountain limestone, ganister, and quartz porphyry. At Hexthorpe Flats, near Doncaster, striated Carboniferous limestone with encrinites has been found, and between Hexthorpe

and Balby the ground is covered with drifted pebbles and fragments of limestone. The Magnesian limestone escarpment south of Conisborough is strewed for some miles with patches of drifted pebbles, of quartz, sandstone, and Trias.

This evidence points to glaciation from the north and north-east by two movements of ice. Two distinct tills, separated by warp and pockets of sand, are found at Staincross, the lower with Carboniferous boulders and the upper with Lake Country rocks. The drift patches are also of two kinds, one set being of a specially Carboniferous type, and the other rich in Lake Country rocks. It is the latter type that forms the Conisborough and Balby clays. In the Balby pits there is also found a large percentage of Middle Coal Measure material, which forms a perplexing mixture to explain.

The author suggests that there was a double glaciation of this area early in the Glacial Period, first by Pennine ice, and secondly by the Tees glacier.

It seems probable that at the commencement of the Glacial Period, before the Irish Sea was filled with ice, the Pennine Chain was an area of great snowfall, and extensive glaciers were formed in the valleys of Western Yorkshire. These glaciers would probably send down considerable streams of ice into the central plain, laden with Mountain and Yoredale limestones, cherts, ganisters, and Carboniferous sandstones. As the Glacial Period advanced the pressure of the Norwegian ice forced the Tees glacier into the Vale of York, and this in its turn would push back the Pennine ice into the lowlands of Airedale and over the low watershed between the Aire and Don, inside the Magnesian limestone escarpment, where it spreads out westwards and southwards as far as Staincross, Rotherham, and Conisborough. This seems to have been the line of farthest extent of this glacier, which, though it interfered for a time with the drainage of the Don, does not appear to have passed through the gorge at Conisborough.

The country south of Frickley has undergone extensive denudation since the cutting of the Darfield gorge, and it seems probable that this was effected by this ice, and, on its northward retreat, by the deflected drainage of the Aire and Calder, which, as its course eastwards would still be blocked by the advancing Tees glacier, would find a ready route of flow through Frickley gorge. Thus a large quantity of Middle Coal Measures material must have been carried through the Conisborough gorge into the plain at Doncaster, and would probably be suitably situated for the second glacier to carry forward to Balby. As it has been suggested that this material might be due to a glacier moving down the valley of the Sheaf from Dore and Totley, this question has been carefully considered. The geological surveyors do not record any drift in the valley of the Sheaf, and a careful search of the 6-inch contour maps has not disclosed any valleys which could have carried off the drainage of the upper Don if it had been obstructed by such a glacier at Sheffield. It is therefore concluded that no glacier capable of advancing to Conisborough was formed in the valley of the Sheaf.

The retreat of the first glacier may have been due to a lessening of the snowfall on the Pennine watershed, owing to the shifting of the area of greatest precipitation to the west of the Pennine Chain as the Irish Sea became filled with ice. The evidence, then, points to a second invasion of the Don and Dearne Valleys by ice, the stream this time coming principally from the Tees. This glacier, which had advanced down the central plain, was now, by the retreat of the Pennine ice, enabled to push over the Aire-Don watershed and Magnesian limestone escarpment. Westwards it abutted against the high land of Woolley Edge, and sent down a lobe of ice at Staincross and Monk Bretton into the valley of the Dearne. This second glacier does not, however, seem to have advanced far south of the Barnsley-Adwick-Conisborough curve, and laid down the upper clay of Staincross, the shap granites of Royston and Adwick, and the numerous Lake Country erratics of the district to the north and east of the Dearne. This glacier seems to have advanced over the Magnesian limestone with a south-westerly movement, gradually closing the gorge of the Don and carrying the material of denuded Bunter and limestone beds over the escarpment to the south of Conisborough, of which the pebble drifts are the relics.

This movement does not appear to have extended much farther southwards, as

the Kiveton gorge seems to have presented a clear course for the overflow of the lake formed by the damming back of the drainage. The second glacier appears to have retreated north of the Aire before the overflows at the head of Calderdale were in full swing. The Don and Dearne valleys were, therefore, in all probability, clear of ice during the later part of the Glacial Period, and have been subjected to enormous denudation, both during the Glacial Period and since, which has cleared away the bulk of the boulder clay and only left relics of previously widespread deposits.

ii. *Glacial Lakes and Overflow Valleys.*

Such a series of glacier movements as has just been indicated would divert the normal drainage of the district and produce lakes in the valleys thus dammed up. The boulder clay at Ashfield's Pit, and near the railway station at Conisborough, and at Cadeby, on the opposite side of the Don, shows that this gorge must have been filled with ice up to the 225-foot contour. The scattered patches of drift from Edlington to Clifton and Braithwell, reaching up to 400 feet, indicate that the gorge was entirely closed above the 350-foot contour. This is the general height of the Midland watershed of the Don system, and is only broken through at one point south of Conisborough, the Kiveton Valley (330 feet), near the middle of which one of the sources of the river Ryton takes its rise. These considerations warrant one in assuming the existence of a great glacial lake, rising to the level of the 330-foot contour to the west and south, and dammed back by ice from Conisborough to Barnsley. This lake would overflow by the Kiveton gorge towards Worksop. One cannot expect to find abundant evidences of lake deposits in an area which has suffered so severely by denudation as this; but the geological surveyors map from 4 feet to 9 feet of brick earth and clay resting on gravel at Parkgate, and from 3 feet to 7 feet of brick earth near Wombwell. These indicate a lake both in the Don and Dearne Valleys, covering up the old river gravels.

Following this line of argument, and taking the various patches of drift as the relics of moraines, and therefore as indications of periods of rest in glacial movement, I have attempted to map out the lakes that would be produced at the different positions of the ice-front, and have examined the watersheds to see if overflow channels existed such as would be necessary to drain such lakes. The whole has been plotted out on the 6-inch contoured maps, by which the results have been carefully tested, and a series of lakes made out discharging successively over cols from 175 feet to 335 feet above O.D. These overflow valleys are not of the type so characteristic of Cleveland and the Cheviots. The long period of subaërial denudation to which they have been subjected has worn back their sides so that they are now V-shaped, but they are streamless either in whole or in part, and often the nearest streams cut across their ends.

In spite of this weathering back there has probably been little alteration of their level, and their present levels may be taken approximately as those of the Glacial Period. Some of them are strike-valleys formed by the denudation of the shales between the outcrop of a bed of Carboniferous sandstone and the dip slope of a lower grit. The objections against such valleys as overflows have been carefully considered, but as the movement of the ice seems to have brought its margin parallel to the general strike of the Coal Measures of this area, it is natural that the deflected drainage should sometimes escape by such routes. In considering the course of the first glacier, it seems probable that it would dam up the Dearne at Ardsley and form a lake overflowing by the Stairfoot Valley at 175 feet. A forward movement would carry it to the Wombwell ridge, and the overflow would be by the Wombwell and Swinton strike-valleys. Further south the ice would probably abut against the projecting spur of the 350-foot contour west of Rawmarsh, and hence would form a lake about that level stretching up to Elsecar, Cawthorne, and Bretton. In searching the watershed for a possible overflow for such a lake, a narrow cut through the 350-foot contour was found at the head of the Wentworth Woodhouse Valley, sloping back to the 400-foot contour on each hand, and with a little stream running across each end at right angles to the

direction of the col. By this valley at 335 feet the Elsecar lake would be discharged into a smaller lake held up by the ice in the Wentworth Woodhouse Valley. When the ice laid down the Masbrough and Sitwell Vale patches of drift, the Rother Valley would be blocked, and the glacial drainage would be discharged round the lobe of ice by channels at Greasborough and Sitwell Vale at 275 feet, and thence into the Don by the Hooton Roberts Valley (180 feet). A slight forward movement of the ice to the gravel patches east of Hooton Roberts would close that valley and cause the drainage to discharge by a col on Conisborough Parks at 260 feet.

The second glacier does not seem to have advanced far beyond the curved line stretching from Barnsley through Adwick-on-Dearne to Conisborough. This, by damming the Dearne at Ardsley, would re-form the Barnsley lake, discharging over the Stairfoot col at 175 feet. This drainage would then escape by a narrow notch between Adwick-on-Dearne and Swinton into the Don at Mexborough.

A further advance would bring the Wombwell-Swinton Valleys into use as overflows, and the Hooton Roberts Valley would be the route into the Don. The damming of the Dearne at Barnsley by a lobe of ice would bring into use a couple of small valleys at Barnsley as overflow channels. The gradual advance of the ice across the Conisborough gorge would cause the blocking of the Don, with the formation of a constantly enlarging lake, which would overflow first by the Hooton Roberts Valley (180 feet), and then by a series of cuts through the 275-foot contour on Conisborough Parks, first draining into the Don behind Castle Hill, then, as the Warmsworth watershed was reached by the ice, into the Balby Valley, and, when this was closed by the ice, over the low watershed into the Loversall Valley.

The further advance of the ice-front to Edlington caused a shallow cut to be made through the 300-foot contour, discharging into the Loversall Valley and thence into the Trent. This channel, which bends round in a semicircle, became the permanent course of the Wadsworth drainage on the retreat of the ice, the old channel at Balby having been filled up with till. When the ice rose above the 330-foot contour the gorge of the Don was entirely closed, and the drainage of the great lake, reaching from Bretton Park and Cawthorne, north of Barnsley, to Clay Cross and Heath, south of Chesterfield, would all be discharged by the Kiveton gorge into the river Ryton.

This explanation may be thought to rest too largely on suggestions, but where the evidence is so scattered and imperfect it is difficult to see how this can be avoided if any explanation is to be attempted.

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3. *The Discovery of Human Remains under Stalagmite in Gough's Cave, Cheddar, Somerset.* *By* HENRY N. DAVIES.

The cave is an ancient subterranean waterway in the Carboniferous limestone rocks of the Cheddar Gorge. It has many branches, but we have only to deal with a small fissure on the north side. Excavations have been in progress for twelve years, and the following accumulations have been cleared out:—

(*a*) Recent accumulations, which filled the entrance and covered the upper stalagmitic crust.

(*b*) A calcareous bed, consisting of thin layers of friable stalagmite from 4 inches to 12 inches in thickness.

(*c*) A bed of cave earth, 4 feet to 6 feet in depth, in parts rubbly and stratified, and containing large blocks of limestone which have fallen from the roof.

(*d*) A lower bed of hard crystalline stalagmite, which has underneath it, here and there, beds of sand and pebbles.

These successive deposits pass without a break into the small fissure on the north previously mentioned. While the contents were being removed from this fissure the skull and other bones of the human skeleton were discovered. Some were removed, others left *in situ*, and so the exact position of the body remains fixed

for future reference. The upper stalagmitic crust was 4 inches thick immediately over the skeleton, but became 12 inches thick within 2 yards of the spot. The small dimensions of the fissure and the undisturbed deposits put interment out of the question. The skull was slightly below the level of the pelvic and leg bones, and the whole skeleton was in a doubled-up position in the upper part of the cave earth.

The cranium is of medium size and oval in form. Its measurements are: Maximum length, 185 mm.; maximum width, 130 mm.; cephalic index, 73. The frontal bone has the extreme thickness of 9 mm. The lower jaw, which is fairly massive, is very wide, measuring 120 mm. between the condyles; the teeth in this jaw are well preserved. The very forward slant of the mastoid processes and the large tubercle at the posterior end of the zygomatic arch point to a short powerful neck. The face is much mutilated, but enough remains to show the prominence of the supraorbital ridge and the slight prognathism of the jaws.

The tibia is a remarkable bone. The flatness of the sides and the extreme acuteness of the angular ridge remove it altogether from the normal type. A section through the ridge gives an antero-posterior diameter of 38 mm. and a transverse diameter of 20 mm., which measurements give the exceedingly low index ·526; the bone is thus shown to be the most platycnemic tibia that has yet been measured in our country, The femur is $17\frac{5}{8}$ in. in maximum length. This, by Dr. Beddoe's formula, gives a height for the individual of 5ft. 5in.

Remains of Pleistocene mammalia have been taken from the cave earth of the vestibule, but, with the exception of teeth of horse, not from the fissure in which the human remains were found.

Many flint implements have been found at all levels in the cave earth of vestibule and fissure: blades, borers, saws (?), scrapers, and flakes occur in abundance. They are beautifully patinated, and exhibit much skill in their fabrication, there being little or no secondary working upon the majority of them. Flints of the same form and workmanship are found in cave earth of unmistakable Pleistocene age in French caverns. A small set from Torbryan Cave, Devon, are also exhibited as palæolithic, with a query, in the Natural History Museum, South Kensington.

The circumstances under which, and the position in which, flints are found must be duly considered, as well as form and workmanship, before their age can be ascertained. It is not necessary to take the time which the stalagmite would take to reach 12 inches in thickness into account. It is not the time taken to form the bed, but the period in which it was deposited, that I have tried to arrive at by other means than arithmetical calculation. This period I conclude, from the cumulative evidence adduced, to be Mortillet's 'Magdalénian' Age of Culture, at the close of the Palæolithic Period. If this be so, the human remains form a link between the low types of Neanderthal and Spy and the later Neolithic remains found abundantly in our own country.

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4. *Report on the Exploration of Irish Caves.*—See Reports, p. 288.

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5. *The Geology of the Oban Hills, Southern Nigeria.* *By* John Parkinson.

(*By permission of the Director of the Imperial Institute.*)

In the summer of 1903 the Colonial Office, acting in conjunction with and under advice from the Imperial Institute, decided to establish a Mineral Survey for the Protectorate of Southern Nigeria. The author, who was accompanied by Mr. L. H. L. Huddart, B.A., A.R.S.M., was appointed to this work, and the following notes provide a brief outline of the principal geological features of the district investigated during the first season's work. They form a preliminary account of an area of about 1,500 square miles, covering the eastern part of the country between the Kameruns territory on the east and the Cross River on the north and

west. The valley of the Cross is not included in this paper, except between Itaka, a village about half a day's journey below the international frontier and the Government station of Obubura Hill.

After briefly describing the monotonous belt of mangrove swamps which fringes the coast and the dense creeper-entangled bush which uniformly covers the higher ground of the interior, an attempt is made to classify and to give some account of the various types of crystalline rocks. These form the backbone of the country, and are bordered on their southern and northern sides by sediments of varying character, which from fragmentary fossils are very probably of Cretaceous age. The crystallines are, however, from many points of view the more important group.

The entire series presents a certain uniformity in whatever part of the district it is observed, and consists of mica schists, with which are associated some hornblende schists; a group of fine-grained biotite gneisses and garnetiferous granulites; intrusive granitoid gneisses; garnetiferous and tourmaliniferous pegmatites; granites and aplites. Owing to the exceedingly dense vegetation and the multifarious calls on the time of the traveller in such a country, the order of succession of these rocks must for the present remain uncertain, but it is believed that the order given represents the true sequence in time. The granites vary from rocks so poor in ferro-magnesian minerals as to be practically aplites, to others rich in biotite with large porphyritic crystals of orthoclase. Doubtless these rocks are of different ages.

The latest igneous rocks are dykes of olivine basalt, which occur, though not commonly, in the crystalline series; while the same or a similar rock forms abundant sills in the sedimentary beds of the Cross River and its important tributary the Aweyong. A study of the pebbles collected from various river-beds shows the presence of andesites and porphyries. From the Calabar River, above Uwet, comes an interesting series of rocks, altered by the intrusion of a granite. Specimens contain an orthochlorite, allied to pennine, and ill-formed garnet and andalusite; but mica schists are most abundant, and recall similar rocks to the north and east.

The sediments, which are believed to be approximately of the same age whether found to the north or to the south of the Oban Hills, exhibit slightly different petrographical characters in the two localities.

Everywhere the basement bed is an arkose, derived directly from the degradation of the crystalline rocks, rarely conglomeratic, occasionally false-bedded.

On the Cross River these sandstones are succeeded by shales, and, more rarely, by impure limestones.

On the Aweyong River, for some distance above and below Ogomogon, a variability and rapid alternation of the strata are noticeable; while on the southern side of the Oban Hills this variability in petrographical composition is very marked; thin beds of limestone are found, and the dip, as in the north, is always small.

Some incoherent sandstones found at Calabar, Adiabo, and elsewhere are intermediate in age between these sediments and the river alluvium.

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6. *On Boulders from the Cambridge District, collected by the Sedgwick Club. By* R. H. Rastall, *B.A.*

During the past two years several hundred boulders have been collected, chiefly from the region lying south and west of Cambridge. Among these rhomb-porphyries are fairly common, and other well-known rocks are recognisable.

An examination of about fifty slices has led to the identification of several distinct rock types. Many are clearly referable to the soda-bearing series of South Norway, characterised by ægirine, arfvedsonite, and other peculiar ferro-magnesian minerals. Among these may be mentioned Nordmarkite and the corresponding soda-granite; also a nepheline syenite, near to laurdalite, and the above-mentioned rhomb-porphyries.

Quartz-porphyries are common, and many probably belong to this family.

Porphyritic intermediate and basic lavas from the Cheviots and Central Scotland are very common, and several specimens are of the Garlton plateau family.

A very characteristic quartz-porphyry is recognised by Professor Sjögren as from Dalecarlia.

Many porphyrites and andesites and a very fine Limburgite have not yet been identified.

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7. *On Tidal Action in the Mersey in Recent Years.* *By* JAMES N. SHOOLBRED, *B.A.*, *M.Inst.C.E.*

It is well known that during the past ten years a very considerable improvement has taken place in the sea approaches to Liverpool, in Liverpool Bay and in the lower parts of the river Mersey, by the removal of 16 feet or more in depth of the sandy bar which obstructs the seaward entrance to Liverpool Bay, and by the dredging of certain shoals in the Queen's Channel leading up to Liverpool itself. In carrying out these operations 80 million tons of sand have been dredged during the ten years which have passed, with the result that a minimum depth of 27 feet at the low water of equinoctial spring tides has been secured for the navigation over the bar, and throughout the entire distance up to the Liverpool Landing Stage. The question has been repeatedly raised as to whether the above increased deepening of the approach channels, together with the smoother channel in the river itself, due to the extension of the dock walls, had led to any alteration in the flow of the tidal current or in the range of the tides themselves.

The Committee of the Association appointed, at the instance of Section G, at the meeting last year at Southport, after a careful examination and comparison of tidal records extending over a period of nearly forty years, have reported that after an investigation, both by harmonic analysis and by direct comparison of the tidal curves themselves, no material change, practically, has taken place in the tidal *régime* of the Mersey. Small local alterations, it should be added, in sandbanks and shoals, and due largely to particular current variations, keep going on, as they have been doing for the last eighty years or more—of which we have records. But these alterations can generally be controlled by carefully guarding against any diminution in the tidal scour of the ebb tide, a duty which is entrusted to the Mersey Conservators, who are specially appointed for that purpose.

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8. *Note on certain High-level or Plateau Gravels on the North Side of the Tamisian Area, and their Connection with the Tertiary History of Central England.* *By* A. IRVING, *D.Sc. B.A.*

The author records some results of his observations of these gravels during the last ten years, as supplementary to what he has written in papers which appeared from ten to twenty years ago on the high-level or plateau gravels south of the Thames.[1] He has found these stratified gravels on the north side of the Thames to be strictly comparable in their *structure*, and in their relation to the Eocene formations on which they lie, with those which cap the hills of Berks and Surrey, these hills representing the approximate levels of the ancient plateau out of which the upland valleys and terraces of the Thames area on both sides have been carved by subsequent denudation. The gravels dealt with in this note especially are found in the district of Bishop's Stortford and Stansted, on the high ground bordering the counties of Herts and Essex. They have been omitted by the late Sir Joseph Prestwich in his discussion of the Mundesley and Westleton beds in his three papers given to the Geological Society in 1890.

The *composition* of these stratified gravels is described, and it is pointed out

[1] See *Proc. Geol. Association*, vol. viii. 1893; *Q.J.G.S.*, vol. xlvi. 1890; *Science Gossip*, May and June, 1891; and *Geol. Mag.*, May 1893.

that the evidence afforded by the materials of the gravels points conclusively to their derivation as fluviatile deposits mainly from the Bunter sandstone of the North and West Midlands, but *débris* from the harder Jurassic strata of the Mercian region is common, along with rolled fragments of crystalline rocks (of uncertain derivation) and small sarsens, with much flinty material from the chalk.

They are referred to the period of the great Miocene continental elevation of North-Western Europe, when rivers from the Welsh border and the Derbyshire highlands probably flowed across a 'peneplain' to join the great arterial Tamisian line of drainage of Southern England, through valleys in the chalk marked (*e.g.*) by the gaps at Hitchin and Elsenham. Recent deep well-sections at the latter place and at Bishop's Stortford prove that the valley of the Stort is a buried valley of erosion in the chalk, and probably continuous with the similar buried valley of the Cam. These stratified gravels are conceived to be indexes of the work done by rivers, as sub-atmospheric denudation proceeded during the Miocene period of elevation, and before the present Mercian chalk escarpment was developed, the presence of Jurassic *débris* in the gravels telling us that the Mercian rivers had cut their way by erosion down to the Jurassic rocks.

The present Mercian river system owes its inception probably to the development of a slight anticlinal flexure running roughly S.W. and N.E. in Pliocene times, letting in the waters of the North Sea to deposit the E. Anglian Crag on the one side, and originating the depression of the area of the Wash drainage, as indicated by the dip of the strata seen in the cliffs at Hunstanton. The easterly trend of the Mercian rivers thus brought about is considered to be the main factor in the development of the Mercian chalk escarpment. The evidence of the early Neogene age of these stratified gravels may be thus summed up: (i.) They are of fluviatile origin, and their materials show that they were brought across the Mercian region; (ii.) no rivers could have laid them down where we find them, with present surface-contours; (iii.) they are older than the boulder clay of the district, which everywhere overlies them, with a pretty sharp definition; (iv.) they are older than Stort Valley, which is itself a line of erosion cut into the chalk to a depth of nearly 200 feet; (v.) in one place (at Stansted) they are seen by faulting to have partaken in earth movements affecting the chalk and Reading beds.

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9. *Some Remarkable Occurrences of Struvite Crystals.* *By* Dr. HUGH MARSHALL, *F.R.S.*

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10. *On the Occurrence of Pebbles of White Chalk in Aberdeenshire Clay.* *By* A. W. GIBB.

The record of the Cretaceous period in the North-east of Scotland is a very fragmentary one. The principal traces hitherto noted consist of a deposit of the nature of a Greensand—not proved to be *in situ*—at Moreseat, Cruden, and large numbers of flints scattered over the surface of the ground in the same locality between Buchanness and the Hill of Dudwick.

Further indications of Cretaceous strata have recently been found at Strabathie, in the district of Belhelvie—about five miles north of Aberdeen—in a bed of laminated clay close to the sea. The clay is found to contain pebbles of white chalk in considerable abundance. Some of the pebbles measure nearly a foot in length, but the majority are small. Some of them inclose flints. That they have been worn off an adjoining land surface is shown by the fact that numbers of them are markedly glaciated, and that pebbles of other rocks, identical with or similar to the rocks of the district, are found in the same pit. These facts indicate that Upper Cretaceous beds have once been, and perhaps somewhere are still, *in situ* in the locality.

It has been ascertained by boring that the clay deposit covers a considerable area, and, as fresh exposures are constantly being made in the process of working the bed, further finds may be anticipated.

Section D.—ZOOLOGY.

President of the Section—William Bateson, M.A., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following address:—

In choosing a subject for this Address I have availed myself of the kindly usage which permits a sectional president to divert the attention of his hearers into those lines of inquiry which he himself is accustomed to pursue. Nevertheless, in taking the facts of breeding for my theme, I am sensible that this privilege is subjected to a certain strain.

Heredity—and variation too—are matters of which no naturalist likes to admit himself entirely careless. Everyone knows that, somewhere hidden among the phenomena denoted by these terms, there must be principles which, in ways untraced, are ordering the destinies of living things. Experiments in heredity have thus, as I am told, a universal fascination. All are willing to offer an outward deference to these studies. The limits of that homage, however, are soon reached, and, though all profess interest, few are impelled to make even the moderate mental effort needed to apprehend what has been already done. It is understood that heredity is an important mystery, and variation another mystery. The naturalist, the breeder, the horticulturist, the sociologist, man of science and man of practice alike, has daily occasion to make and to act on assumptions as to heredity and variation, but many seem well content that such phenomena should remain for ever mysterious.

The position of these studies is unique. At once fashionable and neglected, nominally the central common ground of botany and zoology, of morphology and physiology, belonging specially to neither, this area is thinly tenanted. Now, since few have leisure for topics with which they cannot suppose themselves concerned, I am aware that, when I ask you in your familiar habitations to listen to tales of a no man's land, I must forego many of those supports by which a speaker may maintain his hold on the intellectual sympathy of an audience.

Those whose pursuits have led them far from their companions cannot be exempt from that differentiation which is the fate of isolated groups. The stock of common knowledge and common ideas grows smaller till the difficulty of intercommunication becomes extreme. Not only has our point of view changed, but our materials are unfamiliar, our methods of inquiry new, and even the results attained accord little with the common expectations of the day. In the progress of sciences we are used to be led from the known to the unknown, from the half-perceived to the proven, the expectation of one year becoming the certainty of the next. It will aid appreciation of the change coming over evolutionary science if it be realised that the new knowledge of heredity and variation rather replaces than extends current ideas on those subjects.

Convention requires that a president should declare all well in his science; but

I cannot think it a symptom indicative of much health in our body that the task of assimilating the new knowledge has proved so difficult. An eminent foreign professor lately told me that he believed there were not half a dozen in his country conversant with what may be called Mendelism, though he added hopefully, 'I find these things interest my students more than my colleagues.' A professed biologist cannot afford to ignore a new life-history, the Okapi, or the other last new version of the old story; but phenomena which put new interpretations on the whole, facts witnessed continually by all who are working in these fields, he may conveniently disregard as matters of opinion. Had a discovery comparable in magnitude with that of Mendel been announced in physics or in chemistry, it would at once have been repeated and extended in every great scientific school throughout the world. We could come to a British Association audience to discuss the details of our subject—the polymorphism of extracted types, the physiological meaning of segregation, its applicability to the case of sex, the nature of non-segregable characters, and like problems with which we are now dealing—sure of finding sound and helpful criticism, nor would it be necessary on each occasion to begin with a popular presentation of the rudiments. This state of things in a progressive science has arisen, as I think, from a loss of touch with the main line of inquiry. The successes of descriptive zoology are so palpable and so attractive, that, not unnaturally, these which are the means of progress have been mistaken for the end. But now that the survey of terrestrial types by existing methods is happily approaching completion, we may hope that our science will return to its proper task, the detection of the fundamental nature of living things. I say *return*, because, in spite of that perfecting of the instruments of research characteristic of our time, and an extension of the area of scrutiny, the last generation was nearer the main quest. No one can study the history of biology without perceiving that in some essential respects the spirit of the naturalists of fifty years ago was truer in aim, and that their methods of inquiry were more direct and more fertile—so far, at least, as the problem of evolution is concerned—than those which have replaced them.

If we study the researches begun by Kölreuter and continued with great vigour till the middle of the sixties, we cannot fail to see that, had the experiments he and his successors undertook been continued on the same lines, we should by now have advanced far into the unknown. More than this: if a knowledge of what those men actually accomplished had not passed away from the memory of our generation, we should now be able to appeal to an informed public mind, having some practical acquaintance with the phenomena, and possessing sufficient experience of these matters to recognise absurdity in statement and deduction, ready to provide that healthy atmosphere of instructed criticism most friendly to the growth of truth.

Elsewhere I have noted the paradox that the appearance of the work of Darwin, which crowns the great period in the study of the phenomena of species, was the signal for a general halt. The 'Origin of Species,' the treatise which for the first time brought the problem of species fairly within the range of human intelligence, so influenced the course of scientific thought that the study of this particular phenomenon—specific difference—almost entirely ceased. That this was largely due to the simultaneous opening up of lines of research in many other directions may be granted; but in greater measure, I believe, it is to be ascribed to the substitution of a conception of species which, with all the elements of truth it contains, is yet barren and unnatural. It is not wonderful that those who held that specific difference must be a phenomenon of slowest accumulation, proceeding by steps needing generations for their perception, should turn their attention to subjects deemed more amenable to human enterprise.

The indiscriminate confounding of all divergences from type into one heterogeneous heap under the name 'Variation' effectually concealed those features of order which the phenomena severally present, creating an enduring obstacle to the progress of evolutionary science. Specific normality and distinctness being regarded as an accidental product of exigency, it was thought safe to treat departures from such normality as comparable differences: all were 'variations' alike.

Let us illustrate the consequences. Princess of Wales is a large modern violet, single, with stalks a foot long or more. Marie Louise is another, with large double flowers, pale colour, short stalks, peculiar scent, leaf, &c. We call these 'varieties,' and we speak of the various fixed differences between these two, and between them and wild *odorata*, as due to variation; and, again, the transient differences between the same *odorata* in poor, dry soil, or in a rich hedge-bank, we call variation, using but the one term for differences, quantitative or qualitative, permanent or transitory, in size, number of parts, chemistry, and the rest. We might as well use one term to denote the differences between a bar of silver, a stick of lunar caustic, a shilling, or a teaspoon. No wonder that the ignorant tell us they can find no order in variation.

This prodigious confusion, which has spread obscurity over every part of these inquiries, is traceable to the original misconception of the nature of specific difference, as a thing imposed and not inherent. From this, at least, the earlier experimenters were free; and the undertakings of Gärtner and his contemporaries were informed by the true conception that the properties and behaviour of species were themselves specific. Free from the later fancy that but for selection the forms of animals and plants would be continuous and indeterminate, they recognised the definiteness of species and variety, and boldly set themselves to work out, case by case, the manifestations and consequences of that definiteness.

Over this work of minute and largely experimental analysis, rapidly growing, the new doctrine that organisms are mere conglomerates of adaptative devices descended like a numbing spell. By an easy confusion of thought, faith in the physiological definiteness of species and variety passed under the common ban, which had at last exorcised the demon Immutability. Henceforth no naturalist must hold communion with either, on pain of condemnation as an apostate, a danger to the dynasty of Selection. From this oppression we in England, at least, are scarcely beginning to emerge. Bentham's 'Flora,' teaching very positively that the primrose, the cowslip, and the oxlip are impermanent varieties of one species, is in the hand of every beginner, while the British Museum Reading Room finds it unnecessary to procure Gärtner's 'Bastarderzeugung.'

And so this mass of specific learning has passed out of account. The evidence of the collector, the horticulturist, the breeder, the fancier, has been treated with neglect, and sometimes, I fear, with contempt. That wide field whence Darwin drew his wonderful store of facts has been some forty years untouched. Speak to professional zoologists of any breeder's matter, and how many will not intimate to you politely that fanciers are unscientific persons, and their concerns beneath notice? For the concrete in evolution we are offered the abstract. Our philosophers debate with great fluency whether between imaginary races sterility could grow up by an imaginary Selection; whether Selection working upon hypothetical materials could produce sexual differentiation; how under a system of Natural Selection bodily symmetry may have been impressed on formless protoplasm—that monstrous figment of the mind, fit starting-point for such discussions. But by a physiological irony enthusiasm for these topics is sometimes fully correlated with indifference even to the classical illustrations; and for many whose minds are attracted by the abstract problem of inter-racial sterility there are few who can name for certain ten cases in which it has been already observed.

And yet in the natural world, in the collecting-box, the seed-bed, the poultry-yard, the places where variation, heredity, selection may be seen in operation and their properties tested, answers to these questions meet us at every turn—fragmentary answers, it is true, but each direct to the point. For if any one will stoop to examine Nature in those humble places, will do a few days' weeding, prick out some rows of cabbages, feed up a few score of any variable larva, he will not wait long before he learns the truth about variation. If he go further and breed two or three generations of almost any controllable form, he will obtain immediately facts as to the course of heredity which obviate the need for much laborious imagining. If strictly trained, with faith in the omnipotence of selection, he will not proceed far before he encounters disquieting facts. Upon

whatever character the attention be fixed, whether size, number, form of the whole or of the parts, proportion, distribution of differentiation, sexual characters, fertility, precocity or lateness, colour, susceptibility to cold or to disease—in short, all the kinds of characters which we think of as best exemplifying specific difference, we are certain to find illustrations of the occurrence of departures from normality, presenting exactly the same definiteness elsewhere characteristic of normality itself. Again and again the circumstances of their occurrence render it impossible to suppose that these striking differences are the product of continued selection, or, indeed, that they represent the results of a gradual transformation of any kind. Whenever by any collocation of favouring circumstances such definite novelties possess a superior viability, supplanting their 'normal' relatives, it is obvious that new types will be created.

The earliest statement of this simple inference is, I believe, that of Marchant,[1] who in 1719, commenting on certain plants of *Mercurialis* with laciniated and hair-like leaves, which for a time established themselves in his garden, suggested that species may arise in like manner. Though the same conclusion has appeared inevitable to many, including authorities of very diverse experience, such as Huxley, Virchow, F. Galton, it has been strenuously resisted by the bulk of scientific opinion, especially in England. Lately, however, the belief in Mutation, as De Vries has taught us to call it, has made notable progress,[2] owing to the publication of his splendid collection of observations and experiments, which must surely carry conviction of the reality and abundance of Mutation to the minds of all whose judgments can be affected by evidence.

That the dread test of Natural Selection must be passed by every aspirant to existence, however brief, is a truism which needs no special proof. Those who find satisfaction in demonstrations of the obvious may amply indulge themselves by starting various sorts of some annual, say French poppy, in a garden, letting them run to seed, and noticing in a few years how many of the finer sorts are represented; or by sowing an equal number of seeds taken from several varieties of carnation, lettuce, or auricula, and seeing in what proportions the fine kinds survive in competition with the common.

Selection is a true phenomenon; but its function is to *select*, not to create. Many a white-edged poppy may have germinated and perished before Mr. Wilks saved the individual which in a few generations gave rise to the Shirleys. Many a black *Amphidasys betularia* may have emerged before, some sixty years ago, in the urban conditions of Manchester the black var. *doubledayaria* found its chance, soon practically superseding the type in its place of origin, extending itself over England, and reappearing even in Belgium and Germany.

Darwin gave us sound teaching when he compared man's selective operations with those of Nature. Yet how many who are ready to expound Nature's methods have been at the pains to see how man really proceeds? To the domesticated form our fashions are what environmental exigency is to the wild. For years the conventional Chinese primrose threw sporadic plants of the loose-growing *stellata* variety, promptly extirpated because repugnant to mid-Victorian primness. But when taste, as we say, revived, the graceful Star Primula was saved by Messrs. Sutton, and a stock raised which is now of the highest fashion. I dare assert that few botanists meeting *P. stellata* in Nature would hesitate to declare it a good species. This and the Shirleys precisely illustrate the procedure of the raiser of novelties. His operations start from a definite beginning. As in the case of *P. stellata*, he may notice a mutational form thrown off perfect from the start, or, as in the Shirleys, what catches his attention may be the first indication of that

[1] Marchant, *Mém. Ac. roy. des sci.* for 1719; 1721, p. 59, Pls. 6–7. I owe this reference to Coutagne, *L'hérédité chez les vers à soie* (*Bull. sci. Fr. Belg.*, 1902).

[2] This progress threatens to be rapid indeed. Since these lines were written Professor Hubrecht, in an admirable exposition (*Pop. Sci. Monthly*, July 1904) of De Vries' *Mutations-theorie*, has even blamed me for having ten years ago attached *any* importance to continuous variation. Nevertheless, when the unit of segregation is small, something mistakably like continuous evolution must surely exist. (Cp. Johannsen, *Ueb. Erblichkeit in Populationen und in reinen Linien*, 1903.)

flaw which if allowed to extend will split the type into a host of new varieties each with its own peculiarities and physiological constitution.

Let anyone who doubts this try what he can do by selection without such a definite beginning. Let him try from a pure strain of black and white rats to raise a white one by breeding from the whitest, or a black one by choosing the blackest. Let him try to raise a dwarf ('Cupid') sweet pea from a tall race by choosing the shortest, or a crested fowl by choosing the birds with most feather on their heads. To formulate such suggestions is to expose their foolishness.

The creature is beheld to be very good after, not before its creation. Our domesticated races are sometimes represented as so many incarnations of the breeder's prophetic fancy. But except in recombinations of pre-existing characters —now a comprehensible process—and in such intensifications and such finishing touches as involve variations which analogy makes probable, the part played by prophecy is small. Variation leads; the breeder follows. The breeder's method is to notice a desirable novelty, and to work up a stock of it, picking up other novelties in his course—for these genetic disturbances often spread—and we may rest assured the method of Nature is not very different.

The popular belief that evolution, whether natural or artificial, is effected by mass-selection of impalpable differences arises from many errors which are all phases of one—imperfect analysis—though the source of the error differs with the circumstances of its exponent. When the scientific advocate professes that he has statistical proofs of the continuity of variation, he is usually availing himself of that comprehensive use of the term Variation to which I have referred. Statistical indications of such continuity are commonly derived from the study, not of nascent varieties, but of the fluctuations to which all normal populations are subject. Truly varying material needs care in its collection, and if found is often sporadic or in some other way unsuitable for statistical treatment. Sometimes it happens that the two phenomena are studied together in inextricable entanglement, and the resulting impression is a blur.

But when a practical man, describing his own experience, declares that the creation of his new breed has been a very long affair, the scientist, feeling that he has found a favourable witness, puts forward this testimony as conclusive. But on cross-examination it appears that the immense period deposed to seldom goes back beyond the time of the witness's grandfather, covering, say, seventy years; more often ten, or eight, or even five years will be found to have accomplished most of the business. Next, in this period—which, if we take it at seventy years, is a mere point of time compared with the epochs of which the selectionist discourses —a momentous transformation has often been effected, not in one character but many. Good characters have been added, it may be, of form, fertility, precocity, colour, and other physiological attributes, undesirable qualities have been eliminated, and all sorts of defects 'rogued' out. On analysis these operations can be proved to depend on a dozen discontinuities. Be it, moreover, remembered that within this period, besides *producing* his mutational character and combining it with other characters (or it may be groups of characters), the breeder has been working up a *stock*, reproducing in quantity that quality which first caught his attention, thus converting, if you will, a phenomenon of individuals into a phenomenon of a mass, to the future mystification of the careless.

Operating among such phenomena the gross statistical method is a misleading instrument; and, applied to these intricate discriminations, the imposing Correlation Table into which the biometrical Procrustes fits his arrays of unanalysed data is still no substitute for the common sieve of a trained judgment. For nothing but minute analysis of the facts by an observer thoroughly conversant with the particular plant or animal, its habits and properties, checked by the test of crucial experiment, can disentangle the truth.

To prove the reality of Selection as a factor in evolution is, as I have said, a work of supererogation. With more profit may experiments be employed in defining the *limits* of what Selection can accomplish. For whenever we can advance no further by Selection, we strike that hard outline fixed by the natural

properties of organisms. We come upon these limits in various unexpected places, and to the naturalist ignorant of breeding nothing can be more surprising or instructive.

Whatever be the mode of origin of new types, no theoretical evolutionist doubts that Selection will enable him to fix his character when obtained. Let him put his faith into practice. Let him set about breeding canaries to win in the class for Clear Yellow Norwich at the Crystal Palace Show. Being a selectionist, his plan will be to pick up winning yellow cocks and hens at shows and breed them together. The results will be disappointing. Not getting what he wants, he may buy still better clear yellows and work them in, and so on till his funds are exhausted, but he will pretty certainly breed no winner, be he never so skilful. For no selection of winning yellows will make them into a breed. They must be formed afresh by various combinations of colours appropriately crossed and worked up. Though breeders differ as to the system of combinations to be followed, all would agree that selection of birds representing the winning type was a sure way to fail. The same is true for nearly all canary colours except in Lizards, and, I believe, for some pigeon and poultry colours also.

Let this scientific fancier now go to the Palace Poultry Show and buy the winning Brown Leghorn cock and hen, breed from them, and send up the result of such a mating year after year. His chance of a winner is not quite, but almost *nil*. For in its wisdom the fancy has chosen one type for the cock and another for the hen. They belong to distinct strains. The hen corresponding to the winning cock is too bright, and the cock corresponding to the winning hen is too dull for the judge's taste. The same is the case in nearly every breed where the sex-colours differ markedly. Rarely winners of both sexes have come in one strain—a phenomenon I cannot now discuss—but the contrary is the rule. Does anyone suppose that this system of 'double mating' would be followed, with all the cost and trouble it involves, if Selection could compress the two strains into one? Yet current theory makes demands on Selection to which this is nothing.

The tyro has confidence in the power of Selection to fix type, but he never stops to consider what fixation precisely means. Yet a simple experiment will tell him. He may go to a great show and claim the best pair of Andalusian fowls for any number of guineas. When he breeds from them he finds, to his disgust, that only about half their chickens, or slightly more, come blue at all, the rest being blacks or splashed whites. Indignantly, perhaps, he will complain to the vendor that he has been supplied with no selected breed, but worthless mongrels. In reply he may learn that beyond a doubt his birds come from blues only in the direct line for an indefinite number of generations, and that to throw blacks and splashed whites is the inalienable property of blue Andalusians. But now let him breed from his 'wasters,' and he will find that the extracted blacks are *pure* and give blacks only, that the splashed whites similarly give only whites or splashed whites—but if the two sorts of 'wasters' are crossed together *blues only* will result. *Selection* will never make the blues breed true; nor can this ever come to pass unless a blue be found whose germ-cells are bearers of the blue character—which may or may not be possible. If the selectionist reflect on this experience he will be led straight to the centre of our problem. There will fall, as it were, scales from his eyes, and in a flash he will see the true meaning of fixation of type, variability, and mutation, vaporous mysteries no more.

Owing to the unhappy subdivisions of our studies, such phenomena as these—constant companions of the breeder—come seldom within the purview of modern science, which, forced for a moment to contemplate them, expresses astonishment and relapses into indolent scepticism. It is in the hope that a little may be done to draw research back into these forgotten paths that I avail myself of this great opportunity of speaking to my colleagues with somewhat wider range of topic than is possible within the limits of a scientific paper. For I am convinced that the investigation of heredity by experimental methods offers the sole chance of progress with the fundamental problems of evolution.

In saying this I mean no disrespect to that study of the physiology of reproduction by histological means, which, largely through the stimulus of Weismann's speculations, has of late made such extraordinary advances. It needs no penetration to see that, by an exact knowledge of the processes of maturation and fertilisation, a vigorous stock is being reared, upon which some day the experience of the breeder will be firmly grafted, to our mutual profit. We, who are engaged in experimental breeding, are watching with keenest interest the researches of Strasburger, Boveri, Wilson, Farmer, and their many fellow-workers and associates in this difficult field, sure that in the near future we shall be operating in common. We know already that the experience of the breeder is in no way opposed to the facts of the histologist; but the point at which we shall unite will be found when it is possible to trace in the maturing germ an indication of some character afterwards recognisable in the resulting organism. Till then, in order to pursue directly the course of heredity and variation, it is evident that we must fall back on those tangible manifestations which are to be studied only by field observation and experimental breeding.

The breeding-pen is to us what the test-tube is to the chemist—an instrument whereby we examine the nature of our organisms and determine empirically what for brevity I may call their genetic properties. As unorganised substances have their definite properties, so have the several species and varieties which form the materials of our experiments. Every attempt to determine these definite properties contributes immediately to the solution of that problem of problems, the physical constitution of a living organism. In those morphological studies which I suppose most of us have in our time pursued, we sought inspiration from the belief that in the examination of present normalities we were tracing the past, the phylogenetic order of our types, the history—as we conceived—of Evolution. In the work which I am now pressing upon your notice we may claim to be dealing not only with the present and the past, but with the future also.

On such an occasion as this it is impossible to present to you in detail the experiments—some exceedingly complex—already made in response to this newer inspiration. I must speak of results, not of methods. At a later meeting, moreover, there will be opportunities of exhibiting practically to those interested some of the more palpable illustrations. It is also impossible to-day to make use of the symbolic demonstrations by which the lines of analysis must be represented. The time cannot be far distant when ordinary Mendelian formulæ will be mere *as in praesenti* to a biological audience. Nearly five years have passed since this extraordinary re-discovery was made known to the scientific world by the practically simultaneous papers of De Vries, Correns, and Tschermak, not to speak of thirty-five years of neglect endured before. Yet a phenomenon comparable in significance with any that biological science has revealed remains the intellectual possession of specialists. We still speak sometimes of Mendel's hypothesis or theory, but in truth the terms have no strict application. It is no theory that water is made up of hydrogen and oxygen, though we cannot watch the atoms unite, and it is no theory that the blue Andalusian fowl I produce was made by the meeting of germ-cells bearing respectively black and a peculiar white. Both are incontrovertible facts deduced from observation. The two facts have this in common also, that their perception gives us a glimpse into that hidden order out of which the seeming disorder of our world is built. If I refer to Mendelian 'theory' therefore, in the words with which Bacon introduced his Great Instauration, 'I entreat men to believe that it is not an opinion to be held, but a work to be done; and to be well assured that I am labouring to lay the foundation, not of any sect or doctrine, but of human utility and power.'

In the Mendelian method of experiment the one essential is that the posterity of each *individual* should be traced separately. If individuals from necessity are treated collectively, it must be proved that their composition is identical. In direct contradiction to the methods of current statistics, Mendel saw by sure penetration that masses must be avoided. Obvious as this necessity seems when one is told, no previous observer had thought of it, whereby the discovery was

missed. As Mendel immediately proved in the case of peas, and as we have now seen in many other plants and animals, it is often impossible to distinguish by inspection individuals whose genetic properties are totally distinct. Breeding gives the only test.

Segregation.

Where the proper precautions have been taken, the following phenomena have been proved to occur in a great range of cases, affecting many characters in some thirty plants and animals. The qualities or characters whose transmission in heredity is examined are found to be distributed among the germ-cells, or gametes, as they are called, according to a definite system. This system is such that these characters are treated by the cell-divisions (from which the gametes result) as existing in pairs, each member of a pair being alternative or *allelomorphic* to the other in the composition of the germ. Now, as every zygote—that is, any ordinary animal or plant—is formed by the union of two gametes, it may either be made by the union of two gametes bearing similar members of any pair, say two blacks or two whites, in which case we call it *homozygous* in respect of that pair, or the gametes from which it originates may be bearers of the dissimilar characters, say a black and a white, when we call the resulting zygote *heterozygous* in respect of that pair. If the zygote is homozygous, no matter what its parents or their pedigree may have been, it breeds true indefinitely unless some fresh variation occurs.

If, however, the zygote be heterozygous, or gametically cross-bred, its gametes in their formation separate the allelomorphs again, so that each gamete contains only one allelomorphic character of each pair. At least one cell-division in the process of gametogenesis is therefore a differentiating or *segregating* division, out of which each gamete comes sensibly pure in respect of the allelomorph it carries, exactly as if it had not been formed by a heterozygous body at all. That, translated into modern language, is the essential discovery that Mendel made. It has now been repeated and verified for numerous characters of numerous species, and, in face of heroic efforts to shake the evidence or to explain it away, the discovery of gametic segregation is, and will remain, one of the lasting triumphs of the human mind.

In extending our acquaintance of these phenomena of segregation we encounter several principal types of complication.

Segregation Absent or Incomplete.—From our general knowledge of breeding we feel fairly well satisfied that true absence of segregation is the rule in certain cases. It is difficult, for instance, to imagine any other account of the facts respecting the American Mulattos, though even here sporadic occurrence of segregation seems to be authenticated. Very few instances of genuine absence of segregation have been critically studied. The only one I can cite from my own experience is that of *Pararge egeria* and *egeriades*, 'climatic' races of a butterfly. When crossed together, they give the common intermediate type of North-Western France, which, though artificially formed, breeds in great measure true. This crossed back with either type has given, as a rule, simple blends between intermediate and type. My evidence is not, however, complete enough to warrant a positive statement as to the total absence of segregation, for in the few families raised from pairs of artificial intermediates some dubious indications of segregation have been seen.

The rarity of true failure of segregation when pure strains are crossed may be judged by the fact that since the revival of interest in such work hardly any thoroughly satisfactory cases have been witnessed. The largest body of evidence on this subject is that provided by De Vries. These cases, however, present so many complexities that it is impossible to deal with them now. While so little is definitely known regarding non-segregating characters, it appears to me premature to attempt any generalisation as to what does or does not segregate.

Most of the cases of failure of segregation formerly alleged are evidently spurious, depending on the appearance of homozygotes in the second generation (F_2).

One very important group of cases exists, in which the appearance of a *partial* failure of segregation after the second generation (F_2) is really due to another phenomenon. The visible character of a zygote may, for instance, depend on the coexistence in it of two characters belonging to distinct allelomorphic pairs, each capable of being independently segregated from its fellow, and forming independent combinations. For the demonstration of this important fact we are especially indebted to Cuénot.[1] We have indications of the existence of such a phenomenon in a considerable range of instances (mice, rabbits (Hurst), probably stocks and sweet peas).

Nevertheless, there are other cases, not always easy to distinguish from these, where *some* of the gametes of F_1 certainly carry on heterozygous characters unsegregated. As an example, which seems to me indisputable, I may mention the so-called 'walnut' comb, normal to Malay fowls. This can be made artificially by crossing rose-comb with pea-comb, and the crossbred then forms gametes, of which one in four bears the compound unsegregated.[2] We may speak of this as a true *synthesis.*

In another type of cases segregation occurs, but is not sharp. The gametes may then represent a full series ranging from the one pure form to the other. Such cases occur in regard to some colours of *Primula sinensis*, and the leg-feathering of fowls (Hurst). In the second generation a nearly complete series of intermediate zygotes may result, though the two pure extremes (if the case be one of blending characters) may still be found to be pure.

Resolution and Disintegration.—Besides these cases, the features of which we now in great measure comprehend, we encounter frequently a more complex segregation, imperfectly understood, by which gametes of new types, sometimes very numerous, are produced by the crossbred. Each of these new types has its own peculiarities. We shall, I think, be compelled to regard these phenomena as produced either by a *resolution* of compound characters introduced by one or both parents, or by some process of *disintegration*, effected by a breaking-up of the integral characters followed by recombinations. It seems impossible to imagine simple recombinations of pre-existing characters as adequate to produce many of these phenomena. Such a view would involve the supposition that the number of characters pre-existing as units was practically infinite—a difficulty that as yet we are not obliged to face. However that may be, we have the fact that resolutions and disintegrations of this kind—or recombinations, if that conception be preferred—are among the common phenomena following crossing, and are the sources of most of the breeder's novelties. As bearing on the theoretical question to which I have alluded, we may notice that it is among examples of this complex breaking-up that a great proportion of the cases of partial sterility have been seen.

No quite satisfactory proof as to the actual moment of segregation yet exists, nor have we any evidence that all characters are segregated at the same cell-division. Correns has shown that in maize the segregation of the starch character from the sugar character must happen before the division forming the two generative nuclei, for both bear the same character. The reduction-division has naturally been suggested as the critical moment. The most serious difficulty in accepting this

[1] When $abc \ldots \times \alpha\beta\gamma \ldots$ gives in F_1 or F_2 a character (not seen in the original parents), which from F_2 or later may breed true: not because $a\alpha$, $b\beta$, $c\gamma$ do not severally segregate, but through simultaneous homozygosis of, say, aa and $\beta\beta$, giving a zygote $aa\beta\beta c\gamma \ldots$ which will breed true to the character $a\beta$.

[2] Owing to this behaviour, and to the simultaneous production of single-comb (? by resolution), there are, even in pure Malays, five types of individuals, all with 'walnut' combs—as yet indistinguishable—formed by gametic unions $r \times p$, $rp \times rp$, $rp \times r$, $rp \times p$, $rp \times s$. Of these kinds three can at once be distinguished by crossing with single; but whether $r \times p$ can be distinguished from $rp \times s$ we do not yet know [r, rose; p, pea; s, single; rp, walnut.] In this example four allelomorphs are simultaneously segregated, one being compound. Neglecting sexual differentiation, there are therefore *ten* gametically distinct types theoretically possible; but of these only *four* are distinguishable by inspection.

view, as it seems to me, is the fact that somatic divisions appear sometimes to segregate allelomorphs, as in the case of Datura fruits, and some colour-cases.

In concluding this brief notice of the complexities of segregation I may call attention to the fact that we are here engaged in no idle speculation. For it is now possible by experimental means to distinguish almost always with which phenomenon we are dealing, and each kind of complication may be separately dealt with by a determination of the properties of the extracted forms. Illustrations of a practical kind will be placed before you at a subsequent meeting.

The consequence of segregation is that in cases where it occurs we are rid of the interminable difficulties which beset all previous attempts to unravel heredity. On the older view, the individuals of any group were supposed to belong to an indefinite number of classes, according to the various numerical proportions in which various types had entered into their pedigree. We now recognise that when segregation is allelomorphic, as it constantly is, the individuals are of three classes only in respect of each allelomorphic pair—two homozygous and one heterozygous. In all such cases, therefore, fixity of type, instead of increasing gradually generation by generation, comes suddenly, and is a phenomenon of individuals. Only by the separate analysis of individuals can this fact be proved. The supposition that progress towards fixity of type was gradual arose from the study of masses of individuals, and the gradual purification witnessed was due in the main to the gradual elimination of impure individuals, whose individual properties were wrongly regarded as distributed throughout the mass.

We have at last the means of demonstrating the presence of integral characters. In affirming the integrity of segregable characters we do not declare that the size of the integer is fixed eternally, as we suppose the size of a chemical unit to be. The integrity of our characters depends on the fact that they *can* be habitually treated as units by gametogenesis. But even where such unity is manifested in its most definite form, we may, by sufficient searching, generally find a case where the integrity of the character has evidently been impaired in gametogenesis, and where one such individual is found the disintegration can generally be propagated. That the size of the unit may be changed by unknown causes, though a fact of the highest significance in the attempt to determine the physical nature of heredity, does not in the least diminish the value of the recognition of such units, or lessen their part in governing the course of Evolution.

The existence of unit-characters had, indeed, long been scarcely doubtful to those practically familiar with the facts of variation,[1] but it is to the genius of Mendel that we owe the proof. We knew that characters could behave as units, but we did not know that this unity was a phenomenon of gametogenesis. He has revealed to us the underworld of gametes. Henceforth, whenever we see a preparation of germ-cells we shall remember that, though all may look alike, they may in reality be of many and definite kinds, differentiated from each other according to regular systems.

Numerical Relations of Gametes and their Significance.

In addition to the fact of segregation, Mendel's experiments proved another fact nearly as significant; namely, that when characters are allelomorphic, the gametes bearing each member of a pair generally are formed in equal numbers by the heterozygote, if an average of cases be taken. This fact can only be regarded as a consequence of some numerical symmetry in the cell-divisions of gametogenesis. We already know cases where individual families show such departure from normal expectation that either the numbers produced must have been unequal, or subsequent disturbance must have occurred. But so far no case is known *for certain* where the average of families does not point to equality.

The fact that equality is so usual has a direct bearing on conceptions of the physical nature of heredity. I have compared our segregation with chemical

[1] Cp. De Vries, *Intracellulare Pangenesis*, 1889.

separation, but the phenomenon of numerically symmetrical disjunction as a feature of so many and such different characters seems scarcely favourable to any close analogy with chemical processes. If each special character owed its appearance to the handing on of some complex molecule as a part of one chemical system, we should expect, among such a diversity of characters and forms of life, to encounter some phenomenon of valency, manifested as numerical inequality between members of allelomorphic pairs. So far, equivalence is certainly the rule, and where the characters are simply paired and no resolution has taken place, this rule appears to be universal as regards averages. On the other hand, there are features in the distribution of characters after resolution, when the second generation (F_2) is polymorphic in a high degree, which are not readily accounted for on any hypothesis of simple equivalence; but none of these cases are as yet satisfactorily investigated.

It is doubtful whether segregation is rightly represented as the separation of *two* characters, and whether we may not more simply imagine that the distinction between the allelomorphic gametes is one of presence or absence of some distinguishing element. De Vries has devoted much attention to this question in its bearings on his theory of Pangenesis, holding that cases of both kinds occur, and attempting to distinguish them. Indications may certainly be enumerated pointing in either direction, but for the present I incline to defer a definite opinion.

If we may profitably seek in the physical world for some parallel to our gametic segregations, we shall, I think, find it more close in mechanical separations, such as those which may be effected between fluids which do not freely mix, than in any strictly chemical phenomenon. In this way we might roughly imitate both the ordinary segregation, which is sensibly perfect, and the curious impurity occasionally perceptible even in the most pronounced discontinuities, such as those which divide male from female, petal from sepal, albino from coloured, horn from hair, and so on.

Gametic Unions and their Consequences.

Characters being then distributable among gametes according to regular systems, the next question concerns the properties and features presented by the zygotes formed by the union of gametes bearing different characters.

As to this no rule can as yet be formulated. Such a heterozygote may exhibit one of the allelomorphic characters in its full intensity (even exceeding it in special cases, perhaps in connection with increased vigour), or it may be intermediate between the two, or it may present some character not recognisable in either parent. In the latter case it is often, though not always, reversionary. When one character appears in such intensity as to conceal or exclude the other it is called *dominant*, the other being *recessive*. It may be remarked that frequently, but certainly not universally (as has been stated), the phylogenetically older character is dominant. A curious instance to the contrary is that of the peculiar arrangement of colours seen in a breed of game fowls called Brown-breasted, which in combination with the purple face, though certainly a modern variation, dominates (most markedly in females) over the Black-breasted type of *Gallus bankiva*.

In a few cases irregularity of dominance has been observed as an exception. The clearest illustration I can offer is that of the extra toe in fowls. Generally this is a dominant character, but sometimes, as an exceptional phenomenon, it may be recessive, making subsequent analysis very difficult. The nature of this irregularity is unknown. A remarkable instance is that of the blue colour in maize seeds (Correns; R. H. Lock). Here the dominance of blue is frequently imperfect, or absent, and the figures suggest that some regularity in the phenomenon may be discovered.

Mendel is often represented as having enunciated dominance as a general proposition. That this statement should still be repeated, even by those who realise the importance of his discoveries, is an extraordinary illustration of the oblivion that has overwhelmed the work of the experimental breeders. Mendel makes the specific statement in regard to certain characters in peas which do behave thus, but his proposition is not general. To convict him of such a delusion

it would be necessary to prove that he was exceptionally ignorant of breeding, though on the face of the evidence he seems sufficiently expert.

A generalisation respecting the consequences of heterozygosis possessing greater value is this. When a pair of gametes unites in fertilisation the characters of the zygote depend directly on the constitution of these gametes, and not on that of the parents from which they came. To this generalisation we know as yet only two clear exceptions. These very curious cases are exactly alike in that, though segregation obviously occurs in a seed-character, the seeds borne by the hybrid (F_1) all exhibit the hybrid character, and the consequences of segregation in the particular seed-character are not evident till the seeds (F_3) of the second (F_2) generation are determinable. Of these the first is the case of indent peas investigated especially by Tschermak. Crossed with wrinkled peas I have found the phenomena normal, but when the cross is made with a round type the exceptional phenomenon occurs. The second case is that discovered by Biffen in the cross between the long-grained wheat called Polish and short-grained Rivett wheat, demonstrations of which will be laid before you. No satisfactory account of these peculiarities has been yet suggested, but it is evident that in some unexplained way the maternal plant-characters control the seed-characters for each generation. It is, of course, likely that other comparable cases will be found.

Appearances have been seen in at least four cases (rats, mice, stocks, sweet peas) suggesting at first sight that a heterozygosis between two gametes, *both* extracted, may give, *e.g.*, dominance; while if one, or both, were pure, they would give a reversionary heterozygote. If this occurrence is authenticated on a sufficient scale, we shall of course recognise that the fact proves the presence in these cases of some pervading and non-segregating quality, distributed among the extracted gametes formed by the parent heterozygote. As yet, however, I do not think the evidence enough to warrant the conclusion that such a pervading quality is really present, and I incline to attribute the appearances to redistribution of characters belonging to independent pairs in the manner elucidated by Cuénot. The point will be easily determined, and meanwhile we must note the two possibilities.

Following, therefore, our first proposition that the gametes belong to definite classes, comes the second proposition, that the unions of members of the various classes have specific consequences. Nor is this proposition simply the truistical statement that different causes have different effects; for by its aid we are led at once to the place where the different cause is to be sought—Gametogenesis. While formerly we hoped to determine the offspring by examining the *ancestry* of the parents, we now proceed by investigating the *gametic composition* of the parents. Individuals may have identical ancestry (and sometimes, to all appearances, identical characters), but yet be quite different in gametic composition; and, conversely, individuals may be identical in gametic composition and have very different ancestry. Nevertheless, those that are identical in gametic composition are the same, whatever their ancestry. Therefore, where such cases are concerned, in any considerations of the physiology of heredity, ancestry is misleading and passes out of account. To take the crudest illustration: if a hybrid is made between two races, A, B, and another hybrid between two other races, C, D, it might be thought that when the two hybrids AB and CD are bred together, four races, A, B, C, and D, will be united in their offspring. This expectation may be entirely falsified, for the cell-divisions of gametogenesis may have split A from B and C from D, so that the final product may contain characters of only two races after all, being either AC, BC, AD, or BD. In practice, however, we are generally dealing with *groups* of characters, and the union of all the A group, for instance, with all the C group will be a rare coincidence.

It is the object of Mendelian analysis to state each case of heredity in terms of gametic composition, and thence to determine the laws governing the distribution of characters in the cell-divisions of gametogenesis.

There are, of course, many cases which still baffle our attempts at such analysis, but some of the most paradoxical exceptions have been reduced to order by the accumulation of facts. The consequences of heterozygosis are curiously specific,

and each needs separate investigation. A remarkable case occurred in stocks, showing the need for caution in dealing with contradictory results. Hoary leaves and glabrous leaves are a pair of allelomorphic characters. When glabrous races were crossed with crossbreds, sometimes the results agreed with simple expectation, while in other cases the offspring were all hoary when, in accordance with similar expectation, this should be impossible. By further experiment, however, Miss Saunders has found that *certain* glabrous races crossed together give nothing but hoary heterozygotes, which completely elucidates such exceptions. There is every likelihood that wherever segregation occurs similar analysis will be successful.

Speaking generally, in every case the first point to be worked out is the magnitude of the character-units recognised by the critical cell-divisions of gametogenesis, and the second is the specific consequence of all the possible combinations between them. When this has been done for a comprehensive series of types and characters, it will be time to attempt further generalisation, and perhaps to look for light on that fundamental physiological property, the power of cell-division.

Segregation and Sex.—Acquaintance with Mendelian phenomena irresistibly suggests the question whether in *all* cases of families composed of distinct types the distinctness may not be primarily due to gametic segregation. Of all such distinctions none is so universal or so widespread as that of sex: may it not be possible that sex is due to a segregation occurring between gametes, either male, female, or both? It will be known to you that several naturalists have been led by various roads to incline to this view. We still await the proof of crucial experiments; but without taking you over more familiar ground, it may be useful to show how the matter looks from our standpoint. As regards actual experiment, all results thus far are complicated by the occurrence of some sterility in the hybrid generation. Correns, fertilising ♀ *Bryonia dioica* with pollen from ☿ *B. alba* obtained offspring (F_1) *either* ♂ or ♀, with only one doubtful exception. Gärtner found a similar result in *Lychnis diurna* ♀ × ☿ *L. Flos-cuculi* as ♂, but only raised six plants (4 ♂, 2 ♀). From *L. diurna* ♀ × ☿ *Silene noctiflora* as ♂ he got only two plants, spoken of as females which developed occasional anthers. These results give a distinct suggestion that sex may be determined by differentiation among the male gametes, but satisfactory and direct proofs can only be obtained from some case where sterility does not ensue.

Apart, however, from such decisive evidence—which, indeed, would be more satisfactory if relating to *animals*—several circumstances suggest that sex is a segregation-phenomenon. Professor Castle in a valuable essay has called attention to distinct evidence of disturbance in the heredity of certain moths (*Aglia tau* and *lugens*, Standfuss's experiments; *Tephrosia*, experiments of Bacot and others, summarised by Tutt),[1] where the disturbance is pretty certainly connected with sexual differentiation. Mr. Punnett and I are finding suggestions of the same thing in certain poultry cases. Mr. Doncaster has pointed out that the evidence of Mr. Raynor clearly indicates that a certain variety of *Abraxas grossulariata*, usually peculiar to the female, is a Mendelian recessive. It is scarcely doubtful that this will be shown to hold also for some other female varieties, *e.g.*, *Colias edusa*, var. *helice*, &c. We can therefore feel no doubt that there is some entanglement between sex and gametically segregable characters. A curious instance of a comparable nature is that of the Cinnamon canary (Norduijn, &c.), and similar complications are alleged as regards the descent of colour-blindness and hæmophilia.

In one remarkable group of facts we come very near to the phenomenon of sex. Experiments made in conjunction with Mr. R. P. Gregory have shown that the familiar heterostylism of *Primula* is a phenomenon of Mendelian segregation. Short style, or 'thrum,' is a dominant—with a complication;[2] long style, or 'pin,' is recessive; while equal, or 'homostyle,' is recessive to both.

[1] *Trans. Ent. Soc. Lond.*, 1898.

[2] It is doubtful if 'thrum' ever breeds true, as both the other types can do. Perhaps 'thrum' is a *Halbrasse* of De Vries.

Even nearer we come in a certain sweet-pea example, where abortion of anthers behaves as an ordinary Mendelian recessive character.[1] By a slight exaggeration we might even speak of a hermaphrodite with barren anthers as a 'female.'

Consider also how like the two kinds of differentiation are. The occasional mosaicism in Lepidoptera, called 'gynandromorphism,' may be exactly paralleled by specimens where the two halves are two colour-varieties, instead of the two sexes. Patches of *Silene inflata* in this neighbourhood commonly consist of hairy and glabrous individuals,[2] a phenomenon proved in *Lychnis* to be dependent on Mendelian segregation. The same patch consists also of female plants and hermaphrodite plants. Is it not likely that both phenomena are similar in nature? How otherwise would the differentiation be maintained? The sweet-pea case I have spoken of is scarcely distinguishable from this. I therefore look forward with confidence to the elucidation of the real nature of sex—that redoubtable mystery.

We now move among the facts with an altogether different bearing. 'Animals and Plants under Domestication,' from being largely a narration of inscrutable prodigies, begins to take shape as a body of coherent evidence. Of the old difficulties many disappear finally. Others are inverted. Darwin says he would have expected 'from the law of reversion' that nectarines being the newer form would more often produce peaches than peaches nectarines, which is the commoner occurrence. Now, on the contrary, the unique instance of the Carclew nectarine tree bearing peaches is more astonishing than all the other evidence together!

Though the progress which Mendelian facts make possible is so great, it must never be forgotten that as regards new characters involving the addition of some new factor to the pre-existing stock we are almost where we were. When they have been added by mutation, we can now study their transmission; but we know not whence or why they come. Nor have we any definite light on the problem of adaptation; though here there is at least no increase of difficulties.

Besides these outstanding problems, there remain many special points of difficulty which on this occasion I cannot treat—curiosities of segregation, obscure aberrations of fertilisation[3] (occasionally met with), coupling of characters, and the very serious possibility of disturbance through gametic selection. Let us employ the space that remains in returning to the problem of variation, already spoken of above, and considering how it looks in the light of the new facts as to heredity. The problem of heredity is the problem of the manner of distribution of characters among germ-cells. So soon as this problem is truly formulated, the nature of variation at once appears. For the first time in the history of evolutionary thought, Mendel's discovery enables us to form some picture of the process which results in genetic variation. It is simply the segregation of a new kind of gamete, bearing one or more characters distinct from those of the type. We can answer one of the oldest questions in philosophy. In terms of the ancient riddle, we may

[1] Neglecting minor complications, the descent is as follows:—Lady Penzance ♀ × Emily Henderson (long pollen) ♂ gave purple F_1. In one F_2 family, with rare exceptions, *coloured* plants with *dark* axils were fertile, those with *light* axils having ♂ sterile, whites being either fertile or sterile. The ratios indicated are 9 coloured, dk. ax., fertile ♂ : 3 coloured, lt. ax., sterile ♂ : 3 white, fertile ♂ : 1 white, sterile ♂. The fertile whites, therefore, though light-axilled (as whites almost always are) presumably bear the dark-axil character, which generally cannot appear except in association with coloured flowers. This can be proved next year. Some at least of the plants with sterile ♂ are fertile on the ♀ side, and when crossed with a coloured light-axilled type will presumably give only light-axilled plants.

[2] This excellent illustration was shown me by Mr. A. W. Hill and Mr. A. Wallis. A third form, glabrous, with hairy edges to the leaves, also occurs.

[3] In view of Ostenfeld's discovery of parthenogenesis in *Hieracium*, the possibility that this phenomenon plays a part in some non-segregating cases needs careful examination.

reply that the Owl's egg existed before the Owl; and if we hesitate about the Owl, we may be sure about the Bantam. The parent zygote, whose offspring display variation, is giving off new gametes, and in its gametogenesis a segregation of their new character, more or less pure, is taking place. The significance and origin of the discontinuity of variation is therefore in great measure evident. So far as pre-existing elements are concerned, it is an expression of the power of cell-division to distribute character-units among gametes. The initial purity of so many nascent mutations is thus no longer surprising, and, indeed, that such initial purity has not been more generally observed we may safely ascribe to imperfections of method.

It is evident that the resemblance between the parent originating a variety and a heterozygote is close, and the cases need the utmost care in discrimination. If, for instance, we knew nothing more of the Andalusian fowl than that it throws blacks, blues, and whites, how should we decide whether the case was one of heterozygosis or of nascent mutation? The second (F_2) generation from Brown Leghorn × White Leghorn contains an occasional Silver-Grey or Duckwing female. Is this a *mutation* induced by crossing, or is it simply due to a recombination of pre-existing characters? We cannot yet point to a criterion which will certainly separate the one from the other; but perhaps the statistical irregularity usually accompanying mutation, contrasted with the numerical symmetry of the gametes after normal heterozygosis, may give indications in simple cases—though scarcely reliable even there. These difficulties reach their maximum in the case of types which are *continually* giving off a second form with greater or less frequency as a concomitant of their ordinary existence. This extraordinarily interesting phenomenon, pointed out first by De Vries, and described by him under the head of '*Halb-*' and '*Mittel-Rassen*,' is too imperfectly understood for me to do more than refer to it, but in the attempt to discover what is actually taking place in variation it must play a considerable part.

Just as that normal truth to type which we call heredity is in its simplest elements only an expression of that qualitative symmetry characteristic of all non-differentiating cell-divisions, so is genetic variation the expression of a qualitative asymmetry beginning in gametogenesis. Variation is a novel cell-division.[1] So soon as this fact is grasped we shall hear no more of heredity and variation as opposing 'factors' or 'forces'—a metaphor which has too long plagued us.

We cease, then, to wonder at the suddenness with which striking variations arise. Those familiar with the older literature relating to domesticated animals and plants will recall abundant instances of the great varieties appearing early in the history of a race, while the finer shades had long to be waited for. In the sweet pea the old purple, the red bicolor, and the white have existed for generations, appearing soon after the cultivation of the species; but the finer splitting which gave us the blues, pinks, &c., is a much rarer event, and for the most part only came when crossing was systematically undertaken. If any of these had been seen before by horticulturists, we can feel no doubt whatever they would have been saved. An observer contemplating a full collection of modern sweet peas, and ignorant of their history, might suppose that the extreme types had resulted from selective and more or less continuous intensification of these intermediates, exactly inverting the truth.

We shall recognise among the character-groups lines of cleavage, along which they easily divide, and other finer subdivisions harder to effect. Rightly considered, the sudden appearance of a total albino or a bicolor should surprise us less than the fact that the finer shades can appear at all.

At this point comes the inevitable question, What *makes* the character-group split? Crossing, we know, may do this; but if there be no crossing, what is the *cause* of variation? With this question we come sharply on the edge of human

[1] The parallel between the differentiating divisions by which the parts of the normal body are segregated from each other, and the segregating processes of gametogenesis, must be very close. Occasionally we even see the segregation of Mendelian characters among zygotic cells.

knowledge. But certain it is that if causes of variation are to be found by penetration, they must be specific causes. A mad dog is not 'caused' by July heat, nor a moss rose by progressive culture. We await our Pasteur; founding our hope of progress on the aphorism of Virchow, that every variation from type is due to a pathological accident, the true corollary of '*Omnis cellula e cellula.*'

In imperfect fashion I have now sketched the lines by which the investigation of heredity is proceeding, and some of the definite results achieved. We are asked sometimes, Is this new knowledge any use? That is a question with which we, here, have fortunately no direct concern. Our business in life is to find things out, and we do not look beyond. But as regards heredity, the answer to this question of use is so plain that we may give it without turning from the way.

We may truly say, for example, that even our present knowledge of heredity, limited as it is, will be found of extraordinary use. Though only a beginning has been made, the powers of the breeder of plants and animals are vastly increased. Breeding is the greatest industry to which science has never yet been applied. This strange anomaly is over; and, so far at least as fixation or purification of types is concerned, the breeder of plants and animals may henceforth guide his operations with a great measure of certainty.

There are others who look to the science of heredity with a loftier aspiration; who ask, Can any of this be used to help those who come after to be better than we are—healthier, wiser, or more worthy? The answer depends on the meaning of the question. On the one hand it is certain that a competent breeder, endowed with full powers, by the aid even of our present knowledge, could in a few generations breed out several of the morbid diatheses. As we have got rid of rabies and pleuro-pneumonia so we could exterminate the simpler vices. Voltaire's cry 'Écraser l'infâme' might well replace Archbishop Parker's Table of Forbidden Degrees, which is all the instruction Parliament has so far provided. Similarly, a race may conceivably be bred true to some physical and intellectual characters considered good. The positive side of the problem is less hopeful, but the various species of mankind offer ample material. In this sense science already suggests the way. No one, however, proposes to take it; and so long as, in our actual laws of breeding, superstition remains the guide of nations, rising ever fresh and unhurt from the assaults of knowledge, there is nothing to hope or to fear from these sciences.

But if, as is usual, the philanthropist is seeking for some external application by which to ameliorate the course of descent, knowledge of heredity cannot help him. The answer to his question is *No*, almost without qualification. We have no experience of any means by which transmission may be made to deviate from its course; nor from the moment of fertilisation can teaching, or hygiene, or exhortation pick out the particles of evil in that zygote, or put in one particle of good. From seeds in the same pod may come sweet peas climbing five feet high, while their own brothers lie prone upon the ground. The stick will not make the dwarf peas climb, though without it the tall can never rise. Education, sanitation, and the rest, are but the giving or withholding of opportunity. Though in the matter of heredity every other conclusion has been questioned, I rejoice that in this we are all agreed.

The following Papers were read:—

1. *The Coloration of Marine Crustacea.*[1] *By* Professor F. W. Keeble.

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2. *The Miocene Ungulates of Patagonia.* *By* Professor W. B. Scott.

The expeditions sent by Princeton University to Patagonia, under the leadership of the lamented Mr. Hatcher, were extraordinarily successful in collecting fossil

[1] Embodied in the Report on the Colour Physiology of the Higher Crustacea (p. 299).

mammals from the Santa Cruz beds, the Miocene age of which seems now to be sufficiently established. For nearly five years I have been engaged upon the Edentata of those beds, and have only recently turned to the study of the Ungulates, so that the present notice is merely preliminary.

Dr. Roth, of La Plata, has lately published a very important paper, in which he shows that most of the peculiarly South American groups of hoofed animals are characterised by the structure of the periotic region, while two groups, the Litoptema and Astrapotheria, are without this character. On the other hand, all of the orders, including at least the Litoptema, have certain constant characteristics, such as the extensive articulation between the fibula and calcaneum, the convex distal end of the astragalus, which does not rest upon the cuboid, and some peculiarities in the form of the teeth. The limb and foot bones of the Astrapothina are not yet known, and their systematic position is, therefore, still a matter of conjecture. There is a striking similarity between the dentition of these animals and that of the northern genera, *Cadureotherium* and *Metamynodon*, but the form of the skull is so radically different as to make it probable that the resemblance in dentition is analogical only.

It seems likely, therefore, that Roth's term, 'Notoungulata,' may properly be extended to include all of the Santa Cruz hoofed animals, and that all of the groups which agree in the structure of the periotic region, already alluded to, should be regarded as sub-orders of the Toxodontia. This conception is shown in the following provisional table.

NOTOUNGULATA.

I. TOXODONTIA.

1. *Toxodonta.*
2. *Typotheria.*
3. *Homalodotheria.*

II. LITOPTEMA.

III. ? ASTRAPOTHERIA.

While these South American ungulates are singularly different from those of the Northern Hemisphere, it does not seem at all likely that they originated altogether independently of the latter. Ameghino has described a number of genera from pre-Patagonian formations which, though incompletely known, appear to be referable to the Condylarthra, the parent stock of the northern Ungulates. Very probably an early Eocene or late Mesozoic migration brought the Condylarthra into South America, and there, in almost complete isolation, they gradually gave rise to the various peculiar orders and sub-orders of the Notoungulata. The possibility of such migration is shown by the discovery of an armadillo in the Middle Eocene of North America.

FRIDAY, AUGUST 19.

The following Papers and Reports were read :—

1. *Heredity in Stocks.* *By* Miss E. R. SAUNDERS.

Since the rediscovery of Mendel's work experimental evidence of the purity of the germ cells has been found in a rapidly increasing number of examples. Much of this evidence is derived from cases like those studied by Mendel, where the differentiating characters are related to each other as dominant and recessive. In such cases the F_1 generation (DR) show the dominant character, and F_2 individuals the two parental characters in the ratios 3D : 1R *or* 1D : 1R, according as they result from DR × DR or DR × R.

In other cases the results may be complicated by such phenomena as reversion,

gametic coupling of distinct characters, interaction between characters in zygote (such that the second character is not manifested unless the first be also present), resolution, disintegration, &c. Such cases require minute analysis, and several generations may be needed to elucidate them.

In tracing the laws of heredity in garden stocks several such complications are met with.

(1) *Surface character—hoary or glabrous.*—Hoariness is dominant, glabrousness recessive. Simple experiments in the form $DR \times DR$ *or* $DR \times R$, where D is the white-flowered form of *Matthiola incana*, and R, a glabrous ten-week strain, give normal Mendelian ratios in F_2.

In other cases the result as regards hoariness and glabrousness is more complex owing to the different behaviour of various *glabrous* strains, which, as far as can be seen, differ only in *flower colour*. Matings between two sap-coloured recessives, *e.g.*, red glabrous and purple glabrous, give, as expected, glabrous offspring; but the union of the two non-sap-coloured recessives (white and cream), or of a sap-coloured and a non-sap-coloured (red *or* purple × white *or* cream) gives offspring all dominant (hoary), though both parents were glabrous. Similarly, when $R_1 \times R_2$ are recessives of different colours the unions $DR_1 \times DR_2$ and $DR_1 \times R_2$ give no recessives if either of the recessives used is a non-sap-coloured form.

(2) *Flower-colour.*—Various combinations of colours give reversionary purple in F_1. Purple F_1 may also be produced by two *white* parents if they belong to strains differentiated by leaf-surface. Such purple cross-breds may give a simple Mendelian result in F_2, or a variety of new-colour forms may appear. This latter result is commonly seen when cream is one of the parental colours.

In the case (A), white incana × cream glabrous, F_1 is purple hoary. F_2 shows the cross-bred and parental colours (purple, white, cream), and, in addition, three new forms, viz., red, red with cream eye, purple with cream eye. Again, in the case (B), glabrous white × glabrous cream gives at least nine colour-forms in F_2. In both cases the glabrous recessives are all either white or cream. But as the glabrous collectively constitute in case A one-quarter of the whole generation, and in case B presumably one-half, it is evident that the association of hoariness with colour depends on zygotic association and not on gametic coupling. Whether the appearance of these new forms indicates disintegration or simply recombination of pre-existing characters is still uncertain. Creams breed pure at once. Some whites are pure, others are heterozygotes with cream. The number of extracted recessive types resulting from a given union and their specific behaviours are not yet known.

In the experiment last described we have to deal with (1) reversion in colour (2) reversion in a distinct character, leaf-surface; (3) interaction of the two characters in the zygote; (4) conceivably disintegration. The regularity with which all these phenomena occur plainly indicates that even these complex appearances result from a fundamentally simple system of Mendelian segregation.

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2. *On the Result of Crossing Japanese Waltzing with Albino Mice. By* A. D. Darbishire.

The Japanese waltzing mice used in this experiment exhibited the well-known restless and spinning movements; and, were it not for patches of yellow fur on the head and shoulders, and sometimes on the rump, they would be albinos—that is to say, they have a piebald yellow-and-white coat and pink eyes. According to my experience and information supplied by breeders, they breed true. With albinos everybody is familiar, but with the established fact that they also breed true this is not the case. When an albino is crossed with a Japanese waltzing mouse, the offspring, in the majority of cases, is a mouse which on first inspection appears undistinguishable from the common house mouse. Sometimes there are white patches on the coat of greater or less extent than the grey; in a few instances the coat was yellow, and in a few others it was black or black-and-

white; but to the statement that the hybrids have black eyes there was no exception in the cases, which exceeded three hundred, that I have bred. The hybrids never exhibit waltzing movements, and from the description of their coloration it is evident that they are never albinos. When such hybrids are bred together they produce a population which, considered from the point of view of its colour, falls into three categories: the first is black eye and coloured coat, under which heading come half of the population—mice, therefore, which resemble their parents; the second is pink eye and coloured coat, and includes a quarter of the population, individuals presenting the same features of eye and coat colour as those exhibited by the Japanese waltzing mouse; and the third, into which the remaining quarter falls, is pink eye and uncoloured coat—that is to say, it is albino. If we examine the offspring of hybrids from the point of view of their progression, we find that rather less than a quarter waltz, while the rest are normal. The waltzing habit in this population is not always associated with the same arrangement of eye and coat-colour as that with which it is associated in the pure Japanese waltzer, but may be presented by mice falling into any of the three colour categories. To return to the colour question, the albinos, which, it will be remembered, form a quarter of the population produced by mating the hybrids, breed absolutely true; the pink-eyed mice with coloured coats breed nearly true, and the black-eyed individuals with coloured coats produce, when paired together, albinos, pink-eyed mice with coloured coats, and black-eyed mice with coloured coats, but in what proportions I have not yet determined. Some of the facts which have come to light seem confirmatory of the Mendelian interpretation of these phenomena, while others are describable in terms of either Galton's or Pearson's formula of ancestral inheritance. I do not think, therefore, that I am justified in forming an opinion on the question of the relative validity of these two interpretations of the facts already observed, and until more data have been collected I do not propose to do so.

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3. *Experiments on Heredity in Rabbits. By* C. C. HURST, *F.L.S.*

An inbred pair of albino Angoras was crossed reciprocally with an inbred pair of Belgian hares (F_1), and the hybrid progeny were bred with one another for two generations (F_2 and F_3). Four characters were under observation, each of which was inherited independently of the other.

1. *Angora Coat.*—In F_1 the angora coat was always recessive to the normal coat, which was completely dominant. In F_2 and F_3 this pair of structural characters followed the Mendelian laws of segregation and gametic purity simply and without exception.

2. *Albinism.*—In F_1 the albino character was always recessive to the normal character, which was dominant, and in F_2 and F_3 followed the ordinary Mendelian rules.

3. *Coat Colour.*—In F_1 brown × albino gave all with wild grey coats. In F_2 the hybrid greys bred together gave a ratio of 9 grey : 3 black : 4 albino. Experiments in F_3 proved that the black factor was not introduced by the original brown parent, but *by the albino,* which, though gametically pure as regards simple albinism, was at the same time carrying the distinct factor for black coat colour.

These results in rabbits confirm the important results already gained by Cuénot in mice.

The F_2 greys proved to be of four kinds—viz., pure grey, grey containing black, grey containing albino, and grey containing black and albino. The F_2 blacks were of two kinds—viz., pure black and black containing albino. The F_2 albinos were of three kinds—viz., albino containing grey, albino containing black, and albino containing grey and black. These results are in accordance with the Mendelian expectation, which is—

$$\underbrace{1G : 2G(B) : 2G(A) : 4G(B)(A)}_{9\text{ grey}} : \underbrace{1B : 2B(A)}_{3\text{ black}} : \underbrace{1A(G) : 2A(G)(B) : 1A(B)}_{4\text{ albino}}$$

One point, however, remains to be cleared up, and that is, the absence of browns in F_2 and F_3, these being in all cases apparently displaced by greys.

4. *Dutch Markings.*—In F_1 the offspring from one albino were, as a rule, uniform in colour, like the coloured parent, while those from the other albino were all more or less marked with white on the fore extremities. In F_2 and F_3 the uniform hybrids were, as a rule, constant, while the marked ones produced a proportion of true Dutch-marked rabbits, as well as the ordinary-marked and some uniform ones.

These results suggest that one albino contained the factor for Dutch markings while the other albino did not. Experiments are now in progress to work out this interesting question.

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4. *Experiments on Heredity in Fowls.* *By* R. C. PUNNETT.

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5. *An 'Intermediate' Hybrid in Wheat.* *By* R. H. BIFFEN.

In the majority of cases investigated up to the present one character of a given pair (the dominant) masks the other (recessive) in the first generation (F_1).

In the case of *Triticum Polonicum* (Polish wheat) × *T. turgidum* (Rivet wheat) and its reciprocal, the hybrid does not show this sharp separation of dominant and recessive characters, it being intermediate between the parents with regard to certain pairs. Thus in Polish wheat the glumes, grain, and internodes of the spike are long, and it ripens early; in Rivet wheat the glumes, grain, and internodes are short and it ripens late; whilst the hybrid has an intermediate length of glumes, grains, and internodes, and also ripening period. The hybrid has therefore a distinct character of its own in which one cannot recognise definite dominant and recessive characters. However, in the following generation (F_2) the splitting is of the type which Mendel's work has made so familiar to us. We find long, intermediate, and short glumes, early, intermediate, and late ripening, &c., in the proportion of 1 : 2 : 1, showing that, in spite of the fact that there is no marked distinction into the usual dominant and recessive characters, the gametes are still pure with respect to the characters they carry.

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6. *Experiments on the Behaviour of Differentiating Colour-characters in Maize.* *By* R. H. LOCK, *B.A.*

Maize as grown in Ceylon is of a flint variety, but shows a complex mixture of the colours white, yellow, blue, and red.

White, yellow, and blue grains occur mixed in the same cob. The red colour appears either in all the grains of a cob or not at all.

The problem attempted was to discover, by the method of growing the offspring obtained by definite pollination, how far these several colour-characters conform to Mendel's law.

When a few yellow grains appear in an otherwise white cob such grains must be supposed to be the result of accidental impregnation of pollen bearing the yellow character. On sowing these grains and fertilising the female flowers with the pollen of a white variety the plants yield 50 per cent. of yellow and 50 per cent. of white grains within the limits of error due to the size of the samples afforded by the cobs, which contain as a rule from 300 to 800 grains.

Blue grains, appearing in the same way in an otherwise white cob, when treated as above yielded, as a rule, a much smaller percentage of blue grains—*e.g.*, 30 per cent.—and the proportion is also more variable. The intensity of the blue colour also varies considerably. But on sowing the grains from such a cob, *i.e.*, one with 30 per cent. of blue grains, and pollinating with white, it was found that the blue colour reappeared in the offspring of approximately 50 per cent. of the original grains; *i.e.*, in those of the 30 blue grains, *and* in those of 20 out of

the remaining 70 white grains. It appears, therefore, that Mendel's law (as enunciated by Correns, namely, that the germ cells represent in equal numbers all possible combination of paired characters, no two members of the same pair occurring in the same germ cell) is truly followed, but that there is considerable irregularity in dominance.

The red colour does not appear as an immediate consequence of cross-fertilisation, and is, therefore, more difficult to deal with. It appears only in the *offspring* of the cross (white × red), being situated in the pericarp, and, therefore, a plant- and not an endosperm-character.

The evidence shows that if a 'red-coated' plant of unknown parentage is crossed with white and the 'red-coated' offspring again crossed by white, 50 per cent. of the plants resulting from this cross will show the red character and 50 per cent. not. It is therefore highly probable that Mendel's law is followed in this case also.

Specimens were exhibited showing various regular combinations of the characters dealt with.

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7. *Experiments on Heredity and Sex-determination in* Abraxas grossulariata. *By* Rev. G. H. Raynor *and* L. Doncaster.

In the currant moth (*Abraxas grossulariata*) a rare variety occurs known as var. *lacticolor* or *flavofasciata*, found hitherto in the female sex alone. The Rev. G. H. Raynor has bred this species for several years, and the following is a summary of his experiments.

Var. *lacticolor* is recessive in the Mendelian sense, not appearing at all in the first cross. In the offspring, of heterozygotes paired together half the females are *lacticolor*, the remainder of the females and all the males being normal *grossulariata* (1). For example, the numbers bred in one family of this class were 25 normal ♂♂, 14 normal ♀♀, 9 *lacticolor* ♀♀; in another, 22 normal ♂♂, 9 normal ♀♀, 9 *lacticolor* ♀♀.

When, however, a *lacticolor* ♀ is paired with a first cross ♂ (namely, L♀ × G(L)♂), among the offspring, not only some of the females, but also some of the males are *lacticolor* (2). The numbers available are not yet enough to determine with certainty what are the proportions; in one family there were 10 normal, 6 *lacticolor* ♂♂, 4 normal and 2 *lacticolor* ♀♀.

The facts may be summarised in genealogical tables thus:—

(1)

L♀ × G♂

G(L)♀ × G(L)♂

1L♀   1G(L)♀   2G♂ (= probably 1G(L)♂ + 1GG♂)

(2)

L♀ × G♂

G(L)♂ × L♀

L♀   G(L)♀   L♂   G(L)♂

The experiments are of importance in relation to Castle's hypothesis that gametes bear one or the other sex, and that certain somatic characters may be coupled with a given sex in the gametes. The hypothesis, if somewhat modified, is in excellent accord with the facts; but until we know the result of the pairing *lacticolor* ♂ × cross-bred ♀ it would be premature to draw far-reaching conclusions.

(In this exhibit were also included, as being of interest to entomologists in general, some of the most striking aberrations Mr. Raynor has reared of this extremely variable species.)

8. *Experiments on Heredity in Web-footed Pigeon.* *By* R. STAPLES-BROWNE.

Cross made.—Web-footed pigeon ♂ × Nun ♀.

Characters.—1. *Foot character.*—The membrane between the digits is extended as far as the toe-nails. This character appears suddenly in a strain of pigeons, birds possessing it being bred from parents with perfectly normal feet.

2. *Head character.*—'Shell.' A tuft of reversed feathers at the back of the head, forming the 'shell.' This character has been bred true in the 'Nun' pigeon for many generations.

Results of Crossing.

—	Description of Experiment	Foot Character			Head Character		
		Birds hatched	Feet webbed	Feet normal	Birds feathered	'Shell' present	'Shell' absent
I.	1902. Web-footed ♂ × Nun ♀	6	0	6	6	0	6
II.	1903. Crossbreds of first generation mated together	12	3	9	9	3	6
III.	(α) 1903. Second pair of ditto	11	0	11	9	2	7
	(β) 1904. (Same pair) ,, ...	6	0	6	5	1	4
IV.	1903. Web-footed ♂ × crossbred ♀ first generation	9	4	5	8	0	8
V.	1904. Same ♂ × second ♀ of same breeding	7	4	3	7	0	7
VI.	1904. Extracted webbed birds from IV. .	4	4	0	1	1	0
VII.	1904. Another pair of same breeding . .	5	5	0	5	0	5
VIII.	1904. Extracted 'shell' birds from II. and III.	5	0	5	5	5	0

The web-footed character appears on hatching, the 'shell' on feathering. The experiments were started in 1902, and include birds hatched up to July 16, 1904.

9. *Fowls and Sweet Peas.* *By* W. BATESON, *F.R.S.*

10. *Report on the Occupation of a Table at the Zoological Station, Naples.*
See Reports, p. 300.

11. *Report on the 'Index Animalium.'*—See Reports, p. 297.

12. *Report on the Influence of Salt and other Solutions on the Development of the Frog.*—See Reports, p. 288.

13. *Report on the Colour Physiology of Higher Crustacea.*
See Reports, p. 299.

14. *Report on the Coral Reefs of the Indian Ocean.*—See Reports, p. 298.

15. *Report on the Occupation of a Table at the Marine Laboratory, Plymouth.*—See Reports, p. 297.

16. *Report on the Zoology of the Sandwich Islands.*—See Reports, p. 298.

17. *Report on the Madreporaria of the Bermuda Islands.* See Reports, p. 299.

MONDAY, AUGUST 22.

The following Papers were read:—

1. *Egyptian Eocene Vertebrates and their Relationships, particularly with regard to the Geographical Distribution of Allied Forms. By* Dr. C. W. Andrews.

2. '*Normentafeln' of the Development of Vertebrata. By* Professor F. Keibel.

The 'Normentafeln' are meant to form a sound foundation for the comparative anatomy of the vertebrata.

Each Normentafel gives (i.) an almost complete series of drawings of embryos; (ii.) tables concerning the degree of development of the various organs, with a few illustrations in the text; the tables furnish data concerning the exact time of appearance of organs which permit of criticism of 'biogenetical law'; (iii.) a bibliography arranged alphabetically and according to subject.

Those already published relate to the pig, chicken, ceratodus, and lizard. The frog by Dr. Kopsch, and the rabbit by Professor Minot and Dr. Taylor, will shortly appear.

3. *On the Embryos of Apes. By* Professor F. Keibel.

The embryos of the apes, of which I have the pleasure of showing you the drawings and photographs, belong partly to the collection of Professor Selenka, who unfortunately died before having completed his investigations. I am indebted to Professor Hubrecht for the rest. Specimens are shown of orang-utang, gibbon, macacus, and semnopithecus. The youngest embryo in my possession measured 1·3 mm., and resembled in its development a human embryo of about 12–14 days, the oldest—measuring 3 cm.—corresponding to a human embryo of 10–12 weeks. The result of this examination, which proves of the greatest general interest, is the close resemblance which the ape embryos show to the human embryos in relative stages. This result Selenka concisely emphasised shortly before his death in the 'Biologische Centralblatt.'

Various differences—apart from the tail—are to be traced by closer study, not only between human and simian embryos, but also between the different species of apes. I do not doubt that it will be possible in course of time to detect differences in the early stages of these various embryos. We are already able to do this without difficulty from the fourth to the fifth week.

4. *On Professor Loos's recent Researches on Ankylostoma (the Miner's Worm). By* A. E. Shipley, *F.R.S.*

Professor Loos, of Cairo, through Dr. Elliot Smith, communicated certain of his recent observations on *Ankylostoma duodenale.*

Particular stress was laid upon the fact that the larvæ can penetrate the unbroken skin without causing any visible lesion of the part.

After thus passing through the skin the larvæ enter the lymph vessels and the

blood vessels, and are swept onward until they reach the right ventricle of the heart, from which they are pumped into the pulmonary circulation. When they reach the small vessels surrounding the air vesicles they pass out of the blood vessels into the air cavities.

From the time the larva perforates the skin until it arrives at the lungs it remains of the same size, but as soon as it reaches the air vesicles it begins to grow rapidly. It then makes its way out of the vesicles into the bronchioles, and, travelling up the bronchi and trachea, emerges through the larynx, and by crawling over the epiglottis passes into the œsophagus, and from thence into the duodenum.

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5. Cytoryctes variolæ *Guarnieri: the Organism of Small-pox.* *By* Professor G. N. Calkins.

In spite of the fact that the organism of small-pox has come to be regarded by perhaps the majority of zoologists as an interesting but highly elusive species of will-o'-the-wisp, I have had the temerity to bring before you still another attempt to describe and classify it.

The present attempt goes back to 1892, when the Italian pathologist, Guarnieri, inoculated a rabbit's cornea with vaccine virus. Upon studying the tissues thus vaccinated he found in the epithelial cells peculiar homogeneous bodies of diverse form and size. He then examined skin from human subjects suffering the mild disorder, vaccinia, and skin from human subjects with the much more malignant disease, small-pox. In both cases he found bodies apparently identical with those previously observed in the rabbit. In the subsequent history of these diseases the peculiar structures came to be known as the 'Guarnieri bodies,' and were usually interpreted as degeneration products, although Guarnieri himself regarded them as Protozoa, and called the organisms *Cytoryctes vacciniæ* and *C. variolæ* respectively.

The main reason why pathologists failed to accept Guarnieri's conclusion seems to be that his so-called organisms did not conform in any way with the postulates which Koch set up for the determination of bacterial disease germs. They had no apparent structure and could not be cultivated on artificial media. These objections, to my mind, were quite disposed of by the admirable experiments of Von Wasielewsky in 1901. He vaccinated a rabbit with a small quantity of virus; from this rabbit a second was vaccinated; from the second, a third, and so on until forty-seven rabbits were successfully inoculated without using the original virus a second time. In all the rabbits, after an appropriate period, the same bodies as those described by Guarnieri were found, and in approximately the same number as in the originally vaccinated rabbit. This result left only one conclusion, viz., that the questionable bodies had undergone growth and multiplication, the attributes of a living organism.

Up to this time the Guarnieri bodies, or Cytoryctes, had been observed only in the cytoplasm. In 1902, Councilman of Harvard discovered peculiar and definite bodies in the nuclei of skin-cells infected with small-pox. He also found the usual cytoplasmic forms. This discovery led him, in April 1903, to publish, with Drs. Magrath and Brinckerhof, the hypothesis that *Cytoryctes vacciniæ* and *C. variolæ* are one and the same organism; further, that the mild disorder, vaccinia, is characterised by the cytoplasmic phase alone, while the malignant disease, small-pox, is characterised by the vaccinia phase, plus the intranuclear phase.

I was invited by Dr. Councilman to try to formulate a life history of the organism, and his splendid material from fifty-five different cases was generously turned over to my use. The results of this study were published this spring.

To a zoologist confronted by the thousands of bizarre structures which fixed and stained small-pox material presents the problem seemed at first to be well-nigh hopeless. Added to the difficulties of interpretation from morphology alone was the fact that nowhere among the Protozoa are similar organisms known. The nearest analogies to the structures observed are in the groups Microsporidia

and the bacteria, and it is because of these far-away resemblances that I shall make a new order for the organism, placing it intermediate between the bacteria on the one side and Microsporidia on the other.

Diseases in lower animals due to Microsporidia are frequently characterised by great virulence and well-marked epidemic tendency. Thus it is, for example, in the Pébrine disease of silkworms and in Lymphosporidiosis of brook trout. Singularly enough, these diseases give rise to characteristic lesions in the skin and body-wall analogous, perhaps, to the vesicles and pustules of small-pox.

The first appearance of the organism in the human skin is a minute homogeneous spherule, as solid apparently as a sperm head in the cytoplasm of an egg. This enlarges and differentiates into two substances—one destined to give rise to the multiplication elements or gemmules, the other forming an enveloping matrix. The organism increases in size until it is larger than the cell nucleus. The gemmules repeat the cycle again and again, thus giving rise to auto-infection of the vaccinia type.

In later stages the gemmules enter the nucleus, where they develop into two kinds of structures; one sort has a central residual mass with peripheral points, the other has a central mass with large surrounding matrix. There is reason to believe that these structures are connected with the sexual generation, the former being a male, the latter possibly a female gametocyte. This point, however, I found impossible to solve, and must leave it for further research.

From the structure, which appears like an egg-cell, arises the pan-sporoblast stage. The young sporoblasts appear as exquisitely minute points of deeply staining substance throughout the matrix, which envelops the central mass mentioned above. These increase in size and ultimately give rise to spores. Meantime the nuclear membrane has been ruptured and the sporoblasts are liberated. The spores form in the same way as the gemmules, but differ from these in being hollow spherules five-tenths of a micron in diameter.

Spores may be found scattered in the cytoplasm and in the nucleus, but it is only in the latter that they can develop further. In the nucleus they grow into structures somewhat like the primary sporoblasts, but they are readily detected. This, so far as I know, is unique among Protozoa, although analogies are found in other groups of animals.

There are thus three modes of auto-infection—viz., gemmule formation, sporulation from the primary sporoblast, and from the secondary sporoblast. All of these together are none too many to account for the rapid spread of the organisms, which in a very few days may infest the entire human skin.

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6. *Certain Biological Aspects in the General Pathology of Malignant New Growths.* *By* J. A. Murray, *M.B.*

From time to time biologists have turned their attention to some of the problems which cancer presents, but their contributions to the subject have not been accepted as final. The limited scope of the individual investigators may well be the principal reason for this want of correlation between the different lines of work. The investigations of the Imperial Cancer Research Fund have been directed by the conviction that it is essential, if progress is to be made, that the facts from widely distinct fields of inquiry should be focussed on the essentials of the problem, and conclusions apparently warranted by one set of observations must be controlled by all the others.

The following different lines of inquiry seem to be of importance at present:

1. Pathological-anatomical, including gross anatomy, as well as histological and cytological investigations.
2. Zoological distribution, including ethnological distribution.
3. Statistical investigations—age distribution in correlation with zoological distribution.
4. Experimental investigations. Transmissibility. Powers of growth of normal and malignant tissue.

Malignant new growths, in common with benign, increase their characteristic parenchyma entirely from their own resources. As soon as a malignant new growth is recognisable as such, it is marked off anatomically and physiologically from its surroundings. This phenomenon, now well established, is sufficiently remarkable when it is borne in mind that, histologically, the independent tissue may be indistinguishable from that among which it takes its origin. To a recognition of this fact is due the acceptance accorded to Cohnheim's hypothesis and all its variants. These variants were introduced because of the necessity that was felt to account for the close dependence of the type of growth on the characters of the surrounding tissue, especially when the latter presents well-marked differences at different periods (Thiersch, Ribbert). They are all attempts to account for the behaviour of malignant new growths as independent new organisms, and, whatever acceptance we may accord to the various hypotheses, the fact they seek to explain is incontrovertible. In discussing the experimental investigations some reasons for considering these hypotheses as inadequate will be referred to.

The cells of malignant new growths increase in number by division. Amitosis certainly occurs, but mitotic division is by far the more common, especially in fully developed tumours. Multipolar mitoses are common, but not universal. The active growth and extension of the malignant tissue, as manifested at the growing surfaces of the malignant new growths we have so far examined, is effected by cell-divisions, which, so far as they are mitotic, conform to the ordinary type met with in early development. Apart from multipolar divisions, the number of chromosomes entering the equatorial plate is found constant in each species, and they undergo the ordinary longitudinal splitting. Passing from the growing margin towards the older parts of the growth two sets of changes occur. Many cells undergo the characteristic histological changes peculiar to the tissue among which the tumour has arisen, while others prepare for further mitosis. In some of these the resulting mitosis is characterised by the presence of bivalent chromosomes (heterotype), in number half that found in the younger parts. From the position of these heterotype mitoses in relation to the growing surface of the tumour in which they occur, they must be regarded as a late phenomenon in the life history of the cells, contemporaneous with the histological differentiation going on around them. We have not found evidence of continued proliferation of the immediate descendants of the heterotypical division, and the analogy of animal spermatogenesis suggests that the heterotype initiates a terminal phase in the life history of the cancer cell as in the spermatocyte.

From a consideration of these facts the most divergent conclusions have been drawn. Professor Farmer and his colleagues, who first described the occurrence of heterotypical mitoses in malignant new growths, consider that we have here a transformation of somatic tissue into a kind of reproductive, 'gametoid,' tissue, which, *qua* its gametoid character, is independent and capable of unlimited further growth. This view of the nature of the change which marks the distinction between somatic tissues and malignant new growths had already been advanced by Beatson as a result of clinical considerations. Against this view the general objection may be raised that, while it would explain the occurrence of heterotypical mitoses in malignant new growths, as regards the powers of growth and self-propagation and independence which they manifest it is no explanation at all.

In the vertebrates, where, until now, malignant new growths have alone been found, we have no evidence that gametes, or the tissue which precedes them, possess powers of growth at all comparable to those seen in cancer. The analogies drawn from the vegetable kingdom all concern the interaction of independent organisms, not of different tissues of the same organism.

When, however, the attempt is made to attack this problem by experiment, and artificial propagation of reproductive tissue in animals is tried, the results are in no way different from those obtained with other tissues. The power of independent growth is very limited, and it is found that the power of regeneration of which the testis is capable (along with the thyroid) is confined to the stages before differentiation of gametes has commenced.

The power of propagation of malignant new growths is much greater. While only possible within animals of the same species as that furnishing the initial growth, it is found that the cells can establish themselves and produce masses of tissue as large as the primary growth in successive animals through long periods.

While studying the changes which ensue immediately after transplantation in a tumour of the mouse, we observed nuclear changes which presented a close similarity to a conjugation process. Subsequent observations of an extensive material, embracing over 1,000 tumours of all ages, obtained from three different primary growths, have tended to confirm this interpretation. Thus the same sequence of nuclear changes is again found in later stages, all evidence of its occurrence being wanting in the interval. These observations harmonise very well with the appearances which this tumour presents as it increases in size. Numerous secondary centres of growth are always found around the periphery of older tumours, and these secondary masses may in time outgrow that which preceded them. At once the suggestion arises that the cells which conjugate are those which have passed through a reducing division, but till the complete cycle has been elucidated the thesis outlined above must remain a working hypothesis. It is in harmony with what we know of malignant growths, and renders secondary assumptions unnecessary.

The relation it bears to the question of the initiation of the cancer cycle may be emphasised by a short reference to another line of inquiry—that, viz., of the age incidence of malignant new growths. The life cycle of all the higher animals commences by a fertilisation process, on which cell-division ensues, and the rate of this cell-division continually diminishes as life proceeds. Its gradual cessation manifests itself in the onset of old age, and along with this diminishing power of proliferation there is an increasing liability to malignant new growths. The hypothesis outlined above is an attempt to account for the entrance of a new growth cycle without doing violence to what we know of the general course of cellular activity. It involves the assumption that the ordinary tissues of the body in the terminal phases of their growth may undergo changes by which a conjugation process is possible. Whether this process is effected or not would then determine whether a new cycle of growth be initiated and a malignant new growth result.

In conclusion, an appeal may be made to working zoologists to be on the alert for malignant new growths and allied conditions in the lower animals. Every observation in this direction has a positive value. So far no case of cancer has been found in reptiles among vertebrates, and none at all in invertebrates. When one considers how frequently cytological studies have been undertaken in the latter, it will be appreciated what importance would attach to the discovery of cancer in lower forms of life.

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7. *On the Fertilisation of the Egg of the Axolotl.* *By* J. W. JENKINSON, *M.A.*

The most interesting points that have been brought out by a study of fertilisation in this form are as follows:—

1. The middle-piece of the spermatozoon, after forming the centre of the sperm-sphere and sperm-aster, completely disappears.
2. At a later stage a centrosome is formed from the sperm-nucleus. This divides to give rise to the definitive or cleavage centrosomes.
3. A watery substance collects in vacuoles in the centre of the sperm-sphere.
4. This suggests that the spermatozoon introduces into the ovum a hygroscopic substance. Experiments have shown that a hygroscopic particle is capable of giving rise to an astral structure in a colloid solution.

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8. *Some New and Rare Isopoda taken in the British Area.*[1] *By* W. M. TATTERSALL, *B.Sc.*

The Isopoda dealt with in the following notes were captured during the cruises of the *Helga*, the fishery steamer of the Department of Agriculture for Ireland, off the West Coast of Ireland, and also during the operations of the Department at Ballinakill Harbour, co. Galway.

The most effective trap for these crustaceans is a tow-net attached to the back of a trawl, in such a position that all the bottom living organisms stirred up by the working of the ground rope of the trawl over the sea-floor find their way into it.

Two hauls at 77 miles west of Achill Head (382 fathoms) and 60 miles west of Achill Head (199 fathoms) were particularly productive of new and rare forms. In the latter case the tow-net on the trawl came up full of sand, which on being washed yielded six new species and four species new to Britain.

The following species (eight in number) were found to be new to science, four requiring the formation of new genera, while two have been made the types of new families:—

Typhlotanais proctagon, n. sp.
Bathycopea typhlops, n. gen. et sp.
Sphæroma inerme, n. sp.
Metamunna typica, n. gen. et sp.
Ischnosoma Greenii, n. sp.
Ilyarachna Plunketti, n. sp.
Munnopsoides Beddardi, n. gen. et sp.
Lipomera lamellata, n. gen. et sp.

The species new to Britain include:

Typhlotanais tenuicornis.
Idodrea neglecta.
Gnathia stygius.
Eurycope megalura.
Eurycope latirostris.

Among rarer species of Isopoda taken may be mentioned:

Apseudes hibernicus.
Apseudes grossimanus.
Idothea metallica.
Arcturella dilatata.
Paramunna bilobata, and
Eugerda tenuimana.

The occurrence of many of these species in the British area is particularly interesting, since most of them have been described by Professor Sass in his great work on Norwegian crustacea.

Typhlotanais proctagon differs from all the Norwegian species of the genus by the presence of a spine on the ventrum of the second thoracic segment. In this respect it agrees with *T. longimanus*, *T. Richardii*, *T. spiniventis*, and *T. Kerguelenensis*. From the three former it differs in having the metasome acutely pointed instead of being evenly rounded. From *T. Kerguelenensis*, with which it agrees very closely, it differs in the shape of the cephalon, less prominent rostrum, and shorter and stouter chelipeds. Length, 6 mm.

Bathycopea typhlops, a new genus in the new family *Anciniidæ*, the type genus of which is *Ancinus*, Milne Ed. This form is distinguished by its flat body, small cephalon, absence of eyes, well-marked epimera, the large scythe-like single-branched uropoda, and the evenly pointed metasome. Length, 5 mm.

The family *Anciniidæ* is distinguished by having the first two thoracic limbs in the male and the first only in the female subchelate; while the eyes, when present, are situated on top of the head. The family forms a link between the *Sphæromidæ* and the *Serolidæ*.

Sphæroma inerme? differs from all the members of the genus in having the mouth organs devoid of the large setæ so characteristic in other species. So little is known of the mouth parts of these species that it is with great reluctance that I put this forward as a new species. The mandible is large and blunt.

[1] Full descriptions and figures of these Isopoda will appear in the Reports of the Department of Agriculture for Ireland.

The telson is somewhat acutely pointed, with the lip semitubular, owing to its being arched dorso-ventrally. Length, 9 mm.

Metamunna typica differs from *Pleurogonium* in the presence of eyes and eye-stalks, and from *Paramunna* in the absence of the two lobes to the cephalon. The sides of the metasome are serrated as in *Paramunna bilobata.* Length, 2 mm.

Ischnosoma Greenii differs from the rest of the species of the genus in the absence of large spines from the body, and, in the uniform armature of very small spinules. Uropoda one-jointed, as in *I. spinosum, I. Thomsoni,* and *I. quadrispinosum.* The superior antenna is very characteristic, having the form seen in *I. spinosum.*

Ilyarachna Plunketti is closely allied to *I. longicornis,* but differs in having the outer, instead of the inner, corner of the basal joint of the antennule produced. From *I. hirticeps* it differs in the absence of armature from the cephalon. Length, 4 mm.

Munnopsoides Beddardi, for which a new genus has been erected, differs from the typical Munnopsis in having no palp to the mandible and in having the fifth segment of the mesosome considerably longer and narrower than the rest. The type of the genus is *M. australis* (Beddard), described from the *Challenger* expedition. This species differs from *M. australis* in the larger and more massive cephalon, in the shape of the maxillipeds, and in the shorter and broader fifth segment to the mesosome. Length, 5 mm.

Lipomera lamellata has been made the type of a new family, the *Lipomeridæ,* distinguished by having the seventh segment of the mesosome with its appendages very considerably reduced, and in the uropoda consisting of a broad lamellar plate folded on itself.

The family is very closely related to the *Munnopsidæ,* and especially to the genus *Eurycope,* but the seventh legs, instead of being well developed, with a broad lamellar terminal joint beset with long and strong plumose setæ, are very small and poorly developed, devoid of setæ, and imperfectly jointed. Length, 1.25 mm.

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9. *Some New and Rare Schizopoda from the Atlantic Slope on the West of Ireland.*[1] *By* E. W. L. Holt *and* W. M. Tattersall, *B.Sc.*

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10. *Some New Copepoda from the Atlantic Slopes.* *By* G. P. Farran.

During the dredging cruise to the Porcupine Bank made by the s.s. *Helga* in 1901 a number of new species of Copepods were obtained, which are of particular interest in that the nearest allies of most of them appear to be Northern forms, many of which have been recently described by Professor G. O. Sars in his 'Crustacea of Norway.'

A full account of the Copepods taken on this occasion, together with descriptions and figures of the new species, is in the press, and in the Report of the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland, but in the meantime a short account of the new forms may be of interest.

Bradyetes inermis.—This form, for which a new genus appears to be required, is closely allied to Bradgidius and Bryaxis, agreeing with them in the jointing of the limbs and in the possession of densely setose antennæ. It further agrees with Bryaxis in having the lateral edge of the carapace deeply emarginate.

It differs from both in the absence of spines on the last thoracic segment, and in its much slenderer and less strongly chitinosed form. The rostrum is absent. Length, 2·57 mm.

Bryaxis minor.—This species, except for one strongly marked feature, the second antennæ, agrees minutely with *Bryaxis brevicorni* (G. O. Sars). Its length, however, is only 1·6 mm. In this species the terminal joint of the second antennæ

[1] Will be published in the Reports of the Department of Agriculture, Ireland, 1904.

is longer than the second and bears three well-developed setæ, while in *B. brevicornis* the terminal joint is much reduced and bears three very slender short setæ.

Gaetanus Holtii.—This species has the upright cephalic spine of *Gaetanus miles* and the short antennæ and three-jointed exopodite of the first foot of *G. armiger*, and thus forms a link between the two sections of the genus. It differs from all previously described species in having a spine on the outer edge of the first joint of the exopodite of first foot. Length, 5·1 mm.

Gaetanus minor.—This, the smallest member of the genus, has the short antennæ and forward-directed spine of *G. armiger*. It is alone in having a one-jointed endopodite to its second foot. Length, 2·4 mm.

Scolecithrix emarginata.—This is a large species with a very short abdomen. The last thoracic segment is emarginate. The fifth feet somewhat resemble those of *S. cristata*. First antennæ slightly longer than the body. Length, 4·3 mm.

Scolecithrix ovata.—This species is allied to *S. dentata*, but differs from it in the form of the fifth foot, which consists of a broad oval lamellar joint arising from a small basal. It bears a short backward directed spine on its inner margin, and a more distal very short spine also on the inner margin. Length, 2·3 mm.

Scolecithrix echinata.—This species is closely allied to *S. brevicornis*, but differs in the proportional length of the abdomen, which is contained four times in the cephalothorax instead of $2\frac{1}{2}$ times as in that species The fifth feet also differ in the proportional length of their spines. Length, 1·92 mm.

Xanthocalanus Greenii ♀.—This is a very large, robust species, with short abdomen; the fifth thoracic segments are slightly produced externally, but are not acute; fifth feet very small, three-jointed, the last joint with three spines, one terminal and two lateral. The amimal measures 6 mm. in length, and is in consequence the largest of the genus.

Xanthocalanus pinguis ♀.—This species is moderately robust, with fifth thoracic segments produced and swollen, but ending bluntly. The first antennæ do not reach beyond the fourth thoracic segment. The fifth feet are three-jointed, the last joint with four spines, two terminal and two lateral. Length, 4.5 mm.

Xanthocalanus obtusus ♀.—This species is short and robust. The fifth thoracic segments are not produced, and end in a very obtuse angle on either side. The fifth feet are three-jointed, the second joint being the largest; the terminal joint has two lateral and two terminal spines. Length, 2·4 mm.

Oöthrix bidentatus.—I have thought it necessary to create a new genus for this species. It is very closely allied to the genus Xanthocalanus, and differs mainly in the form of the rostrum, which is broad and truncate, and in the terminal sensory filaments of the first maxillipede, which are short and swollen instead of long and vermicular.

In the species, and possibly in the genus, the fifth thoracic segment is produced on each side into a pair of sharp points. The fifth feet are as in Xanthocalanus. Length, 3 mm.

Lucicutia curta.—This species seems intermediate between *L. plancornis* and *L. longicornis*. The first to fourth feet have three-jointed exopods and endopods. Terminal spine of exopod of fifth foot is contained $1\frac{1}{3}$rd times in the length of the third joint. First antennæ slightly longer than the body. Length, 2·4 mm.

Aegisthus spinulosus.—This species approaches *A. aculeatus* in general form, but the segmentation between the first and second abdominal segments is complete, and the chitinous reticulations on the cephalon are absent. There is a small two-jointed exopod present on the mandible.

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11. *On a New Species of Dolichoglossus.*[1] *By* W. M. Tattersall, *B.Sc.*

The little Enteropneust described below is the first member of the group recorded for British waters. It is true that a species of *Balanoglossus* occurs in the Channel Islands, but that zoologically is in France.

[1] Full descriptions and figures will appear in the Reports of the Department of Agriculture for Ireland.

The specimens belong to the genus *Dolichoglossus* and to a new species of that genus which I propose to call *D. ruber*. It was first found by Mr. G. P. Farran in a dredging from Ballinakill Harbour, co. Galway.

It was later obtained by digging in a mixture of wet coarse sand and mud at extreme low-water spring tides at the same place. The sand must be wet, as dry sand of the same quality yielded no specimens at all. They were found 8–12 inches below the surface, in company with *Solen, Arenicola, Echinocardium, Synapta,* and *Polychæta* of various species.

The species is very fragile, and no whole specimens were obtained. The largest portion taken measured 12·5 cm., and it appeared to be nearly complete.

The colour of the proboscis is a light pinky red; the collar was a deep scarlet, while the rest of the body varied from a reddy brown in the branchial region to a dark brown at the tail end, spotted with lilac.

The animal secretes a large quantity of mucus, especially about the region of the collar. With this mucus it cements the sand in which it is found, in the form of a thick tube, in which it lives, and which must be a considerable protection to its fragile body.

The proboscis is long and attenuated, and is capable of considerable extension and retraction. There is a slight groove extending a little way up the dorsal surface.

The collar is about twice as long as broad, and has a thickened anterior and posterior border. The branchial region is from two and a half to three times as long as the collar, and the number of branchial openings varies from about 56 to 64 pairs.

Mr. Punnett, to whom the specimens were first submitted, kindly informs me that this species has two proboscis pores, thus distinguishing it from all species of the genus except *D. otagoensis.*

The relatively great development of the circular proboscis musculature, arrangement of the longitudinal muscles of the proboscis, the complete and continuous lumen of the stomochord, and the great size of the pericardium are also distinguishing features.

TUESDAY, AUGUST 11.

The following Papers were read:—

1. *The Budgett Memorial.*

(i.) *Note on the Developmental Material of Polypterus obtained by the late Mr. J. S. Budgett. By* J. Graham Kerr.

The material consists of about two hundred eggs and larvæ, ranging from before fertilisation to the ten-day larva. Segmentation is at first almost equal, later on unequal to about the same degree as in *Lepidosiren.* Gastrulation begins with the appearance of a deep groove about the level of the equator. The groove increases in length, forming eventually a closed curve and surrounding the yolky mass of the lower pole, which gradually becomes a typical but enormously large 'yolk plug.' The yolk plug diminishes in size, and eventually disappears, very much as in Amphibia. A medullary plate arises as in the Amphibia, and the edges of this arch inwards in normal fashion to cover in the central canal of the nervous axis. The depression to form the infundibulum, and the deposits of pigment which foreshadow the development of the eyes, appear while the medullary groove is still widely open. After closure of the medullary groove the trunk of the embryo projects anteriorly and posteriorly, by the development of head and tail folds—the axis of the trunk being nearly straight instead of being curled round the egg. At a very early stage there appear two pairs of projections in the head region—anteriorly, the rudiments of two conspicuous cement organs; farther back, the rudiments of the two large external gills. The larva soon develops a tadpole-

like shape, the cement organs forming a conspicuous tubercle on either side, with a deep cup-like depression at its apex, and the external gills assuming a pinnate character. As development goes on the cement organs come to be situated on the upper lip, one on either side. The tail of the larva is purely diphycercal. As regards the internal features of development, the following details may be specially mentioned. The 'swim-bladder' develops as a mid-ventral diverticulum of the pharyngeal region, exactly as a typical lung. The excretory organ of the larva is a pronephros with two tubules on each side. The nephrostomes in the specimens so far examined are in the region of metotic myotomes one and four. When at its *maximum* of functional activity the pronephros becomes a remarkably bulky organ, its bulk being due for the most part to the anterior part of the archinephric duct becoming greatly enlarged and thrown into complicated coils. In the 30 mm. larva, obtained by Budgett on a previous expedition, the anterior tubule is to a great extent degenerate, though it is still distinctly recognisable in the sections.

On the whole, the most striking features of the development of Polypterus are the extraordinary resemblances to the development of Dipneumonous Dipnoans and Amphibians.

It is proposed to publish a detailed account of the developmental phenomena in the Budgett Memorial volume, which is now in course of preparation.

(ii.) *Notes on the Development of* Phyllomedusa hypochondrialis (*Daud*). *By* E. J. Bles.

In material for the study of Anuran development collected by the late Mr. J. S. Budgett and handed over to me, the most complete of the series of stages of forms with large eggs is that obtained in South America of *P. hypochondrialis,* a Hylid. The study of this material was therefore commenced on this form, with the help of Budgett's description, already published,[1] and of his series of sections. I can confirm all his recorded observations, including that of the remarkable ridge formation externally in the early embryo in the branchial region. The ridges are formed by the pushing out of the mesenchym and ectoderm over the surface of the long endodermic gill pouch. The ridges visible externally behind the optic vesicles are, therefore, not the branchial arches, but mark the position of the future clefts, while the depressions on either side of the ridges mark the position of the branchial arches. At this stage the branchial region is spread out flat over the surface of the yolk, and the resemblance to an early embryo of Acipenser is, as Budgett pointed out, very great. As he remarks, the absence of a great cement organ on the mandibular arch does not obscure the likeness. I find, however, that at a later stage, just before hatching, paired cement organs are present, as vestigial organs, disappearing immediately after hatching without having become functional. This fact is significant; it shows that *P. hypochondrialis* must be descended from a form which, like our European *Hyla,* was hatched as a heavily yolked larva and hung from its cement organ until the yolk was absorbed. As the Anura which follow this course all develop from eggs with a relatively small amount of yolk, it follows that the resemblance of *Phyllomedusa* embryos to those of *Acipenser* is due to a comparatively recent increase of the proportion of yolk in the egg, the resemblance being, therefore, secondary. If this view is correct, it will be of great interest to compare the development of other Hylid frogs with that of *Phyllomedusa,* in order to determine how development is influenced in closely related forms by the relative amount of yolk in the egg. The cement organs undergo a remarkable modification just before hatching takes place. The clear outer ends of the columnar cells become very much swollen by an accumulation of secretion, and at the same time other gland-cells dorsal to each cement organ assume the same appearance. The swellings produce an elevated area of ectoderm, which extends upwards on either side of the mouth. The whole arrangement vanishes when the tadpole is hatched. The position of the two

[1] *Q.J.M.S.*, vol. xlii. 1899, p. 317.

bands of cells at the extreme tip of the head, the resemblance to an organ (the frontal gland) in other tadpoles which plays a part in the process of hatching, and the time of its appearance, suggest that this organ is developed in *Phyllomedusa* to assist it in escaping from the egg-membranes.

The thyroid gland in Phyllomedusa differs in an interesting way from that of other tadpoles. It is more like the early thyroid of Petromyzon, as it reaches along the whole length of the floor of the buccal cavity, from the stomodœal membrane in front, to end in a sac behind projecting down to the pericardium. The anterior portion is not a simple groove; the outline of the lumen forms a truncated diamond:  . The subnotochordal rod is very conspicuous, and ends posteriorly in the fork formed by the roots of the aorta.

I find that the pectoral lymph-hearts in this, as in other tadpoles, appear, not at the metamorphosis, but at a very much earlier stage, viz., when the tadpole has still a solid intestine and the yolk has almost disappeared from all the other tissues. The wall of the lymph-heart seems to be derived from an outgrowth on the posterior cardinal vein. Before the valves are formed the lumen of the lymph-heart contains blood-corpuscles.

The Budgett Memorial volume will include a full account of the above and other material (*Hemisus*, &c.) collected in South America and West Africa.

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2. *Rejuvenation.* *By* Charles Sedgwick Minot, *LL.D.*, *Sc.D.*

At the meeting of the Association at Belfast the author presented an outline of his theory of cellular senescence, and referred to its bearings on the problems of differentiation, of heredity, and of sex. In this paper he presents the complement of this theory, namely, the theory of cellular rejuvenation, which he claims must be defined as the increase of the nuclear substance in proportion to the amount of the cell-body (protoplasm). This increase occurs during the period of the segmentation of the ovum, and is the immediate result of impregnation, and itself results in the production of rejuvenated cells, *i.e.*, cells with very small cell-bodies around their nuclei. These cells and their descendants then enter upon a career of cellular senescence. It must be further pointed out that if these views are correct Weismann's theories of the germ-plasm are superfluous.

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3. *An Experiment with Telegony.* *By* Charles Sedgwick Minot, *LL.D.*, *Sc.D.*

The author experimented with females of a known race of guinea-pigs kept by him in stock for many years, and the colours of which were well fixed. A male of entirely different strain was allowed to breed with virgin does, the offspring having about 50 per cent. of the paternal colour. The same females were then allowed to breed by bucks of their own race. In no case was there any trace of the colour of the telegonous father in the second sets of offspring.

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4. *The Harvard Embryological Collection.* *By* Charles Sedgwick Minot, *LL.D.*, *Sc.D.*

The collection belongs to the laboratory of the Harvard Medical School, and is intended to serve as a basis for researches in vertebrate embryology. It now comprises over 800 series of sections of vertebrate embryos. Each series is numbered, and so labelled that the number of each section in the series is readily determined. The collection comprises eighteen central types—namely, Amphioxus, Petromyzon, Squalus, Torpedo, Lepidosteus, Accipenser, Batrachus, Salvellinus, Necturus, Amblystoma, Rana, Lacerta, Gallus, Didelphys, Sus, Lepus, Felis, Homo, to which it is hoped to add Alligator, a snake, a turtle, and the sheep. Of each type regularly graded stages are chosen, and of each stage three series of

sections, in three different planes, are made. To complete the collection for the eighteen types about 400 more series are needed.

The author gave details as to the methods employed in forming the collection, its present extent, the manner in which it has been utilised for scientific researches, and stated his reason for considering the establishment of such collections important as a means of promoting investigations.

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5. *The Precipitin Test in the Study of Animal Relationships.* *By* Dr. George H. F. Nuttall, *F.R.S.*

Referring to a work recently published,[1] in which matters relating to the precipitin test have been very fully considered, the author briefly described the methods of testing by means of precipitating antisera. Two practical applications of the test possess considerable importance. In the first case the test may be applied in legal medicine for the identification of blood-stains in cases of murder, the value of the method having been fully demonstrated in courts of law in Germany, Austria, and other countries, England excepted. In the second case the test has been applied in the study of animal relationships, and in this connection has yielded results of zoological interest. An investigation of the bloods of Primates by means of precipitating antisera for man, chimpanzee, ourang, and monkey have demonstrated a close relationship between Hominidæ and Simiidæ, a more distant one between these and Cercopithecidæ, a slight bond connecting all of these with the New World monkeys. The lemurs do not appear to be connected to the Primates any more than do other mammalia. The gradations in the amount of reaction obtained with different bloods of Primates, as demonstrated by the author, have been recently confirmed by Uhlenhuth on bloods sent him by Dr. Nuttall, with the difference that he obtained results indicating a connection between the lemurs and the other Primates. In view of the fact, however, that Uhlenhuth does not state the strength of his antisera, and makes no mention of his having used other mammalian bloods to exclude the possibility of the reaction he observed being a 'mammalian reaction' (Nuttall), the author held that no connection between the lemurs and other Primates, other than a general mammalian one, has as yet been demonstrated. Preliminary work, undertaken with a view to testing if racial differences can be demonstrated between human bloods by means of the test has given indications which are suggestive. The results of thousands of tests on the bloods of Insectivora, Carnivora, Rodentia, Ungulata, Cetacea, Marsupialia, Aves, Reptilia, Amphibia, Arthropoda, &c., all agree in demonstrating that closely related forms in the sense of descriptive zoology show similarities in blood constitution, and apparently that the degree of reaction is a fair index of the degree of relationship. The test appears to connect the Cetacea with the Ungulata, and, what is sufficiently remarkable, the Reptilia and Aves. The author appealed to zoologists to turn their attention to what appears to be a most promising field of research, wishing his own investigations to be regarded as purely preliminary in character, although they unquestionably establish a new and broad biological principle.

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6. *The Mimetic Resemblance of Diptera for Hymenoptera.*[2] *By* Professor E. B. Poulton, *F.R.S.*

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7. *The Evolution of the Horse.* *By* Professor Henry Fairfield Osborn.

There is a remarkable coincidence of the three entirely independent researches by Messrs. Ewart, Ridgeway, and myself, with the assistance of Mr. Gidley.

[1] Nuttall, *Blood Immunity and Blood Relationship.* Cambridge (University Press), 1904.

[2] Will appear in the *Transactions of the Entomological Society.*

They applied to different periods in the history of the horse by different methods, which nevertheless promised to ultimately form points of contact and close up the wide gap which at present existed between the fossil, the historic, and the recent races of horses. Three years ago the American Museum began especial exploration into the fossil history of the horse, aided by a liberal gift from the Hon. William C. Whitney, former Secretary of the Navy. The object was to connect all the links between the Lower Eocene five-toed and Lower Pleistocene one-toed horses, and ascertain the relations of the latter to the horses, asses, and zebras of Eurasia and Africa. The first great result obtained is the proof of the multiple nature of horse evolution during the American Oligocene and Miocene. Instead of a single series, as formerly supposed, there are five, one leading to Neohipparion, the most specialised antelope-like horse which has ever been found; a second of intermediate form, probably leading through Protohippus to Equus, as Leidy and Marsh supposed; a third leading to the Upper Miocene *Hypohippus*, a persistently primitive, probably forest- or swamp-living horse, with short crowned teeth, adapted to browsing rather than grazing, and three spreading toes; this horse has recently been found in China also. A fourth and fifth line of Oligocene-Miocene horses became early extinct. This polyphyletic or multiple law is quite in harmony with the multiple origin of the historic and recent races of horses, as recently established by Ridgeway and Ewart. The Pliocene horse of America still requires further exploration before we can positively affirm either that all the links to Equus are complete, or that America is indubitably the source of this genus. The Lower Pleistocene of America exhibits a great variety of races, ranging in size from horses far more diminutive than the smallest Shetland to those exceeding the very largest modern draught breeds; yet all these races became extinct, not surviving into the human period, as was the case in South America. The relations of these North American races to those of South America and of Asia and Africa is, again, a subject requiring further investigation, in which it is necessary to exercise the most extreme accuracy. Correspondence and interchange of specimens with other museums is greatly desired.

The paper was illustrated by photographs of a large series of models of osteological preparations, showing the mechanism and breeds of the horse, and of the mounted fossil specimens recently discovered by the Whitney exploring parties.

8. *The Histogenesis of the Blood of the Larva of* Lepidosiren.[1] *By* Dr. T. H. Bryce.

9. *The Hatching of Anuran Tadpoles.* *By* E. J. Bles, *M.A.*

WEDNESDAY, AUGUST 24.

The following Papers were read:—

1. *The Effects Produced by Growing Frog Embryos in Salt and other Solutions.*[2] *By* J. W. Jenkinson.

2. *On the Pacific, Atlantic, Japanese, and other 'Palolos.'* *By* Professor McIntosh, *F.R.S.*

The forms included in these remarks belong to the pelagic fauna, a term more complex than is usually supposed, for it comprises two distinct series, viz.,

[1] Will be published by the Royal Society of Edinburgh.

[2] Embodied in the Report on the Influence of Salt and other Solutions on the Development of the Frog (p. 288).

the permanently pelagic types—such as the Pteropods and *Sagitta*—and the temporarily pelagic—such as the larval stages of sedentary or reptant forms on the bottom of the sea or between tide-marks. Moreover, those larvæ which come from the bottom in fairly deep water pass, more or less, through the whole depth at least twice—viz., when ascending as young larvæ, and when descending as larger forms, each stage being useful, for instance, to fishes of different sizes.

One of the earliest descriptions of the Pacific 'Palolo' is Dr. Gray's (1847),[1] from examples procured by Mr. Stair, and the specimens consisted only of the separated posterior region of the body of an annelid found in immense profusion in the surface waters at certain seasons, and which are used as food by the natives. Mr. Stair then stated that the worms came from the coral reefs. Subsequent observers knew that they dwelt in fissures and crevices of these rocks at and near low-water, and that the swarming of the headless portions as pelagic forms was connected with reproduction. The first head was described and figured by Dr. J. Denis Macdonald, and it was clearly that of a Eunicid. Now Eunicids are very abundant in cracks and fissures of rocks everywhere, and especially in coral reefs, but it has yet to be proved that they bore into the latter. Moreover, epitokous annelids have been familiar to zoologists for a long time, so that the step by which the 'Palolo' of Samoa was connected therewith was brief, for it was evidently the posterior region distended by the reproductive elements. The main point in Mr. Woodworth's observations was the demonstration of the atokous and epitokous regions of the body *in situ*, and as obtained by splitting the edges of the honeycombed coral rocks; though this author attaches much importance to what he calls the thermotropic or heliotropic reaction of the pigment-specks borne on the best-developed central segments of the epitokous region —in connection with the swarming, it would seem that further investigation is necessary—since similar features are observed in other forms devoid of such pigment-specks.

In the Atlantic 'Palolo' (*Eunice fucata*, Ehlers) from the Dry Tortugas and Porto Rico a very similar condition prevails, the posterior epitokous, or sexual region, being thrown off by the annelid, which lives in crevices of the dead and disintegrating coral rock. This posterior region is broader than in the Pacific 'Palolo,' and has no pigment-spots, but it swims freely away in the same manner within three days of the moon's last quarter—June 29–July 28.

In Britain a condition closely approaching that of the foregoing 'Palolos' occurs in various forms; *e.g.*, *Nereis Dumerilii* (Aud. and Ed.), swarms of which occur in various bays, and in *Nereis longissima*. An allied condition occurs in Syllideans, the Cirratulids (*Dodecaceria*), and other annelids.

One of the most interesting Nereids in this connection is the Japanese 'Palolo' (*Ceratocephale osawai*), as recently described by Akira Izuka. The species is much used by the Japanese fishermen as bait, and occurs abundantly in the littoral region, as well as extends into estuaries, tributaries, canals, and ditches, burrowing in mud. It thus approaches the fresh and brackish water Nereids from the Pacific Coast and Hawaii. Early in September it assumes the epitokous condition, the males being brownish, the females bright red. The body considerably increases in breadth. Then the posterior region, comprising two-thirds of the segments, becomes narrower, the animal still being in the mud. This posterior region degenerates and is cast off, even before swarming in October and November, though a few are found swimming with the remains attached. Shortly after the change just mentioned the annelids leave their burrows and become pelagic, and discharge their ova and sperms from the posterior aperture. The swarming usually occurs in four different periods, lasting a few days—periods falling on nights close to the appearance of the new or full moon and just after flood tide. Thus the species quite differs from both the Pacific and the Atlantic 'Palolo' in regard to the process.

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[1] *Ann. Nat. Hist.*, xix., p. 409.

3. *On the Elucidation of Cellular Fields of Force by Magnetic Models. By* Professor MARCUS HARTOG.

The structure developed in the protoplasm of a dividing cell suggests so strongly the magnetic field of force of two unlike poles that the analogy struck the earliest observers. Nevertheless, certain phenomena have remained unexplained by the assumption that the force was analogous to a 'dual force' (Faraday), such as magnetism or electricity; and some have been alleged to be absolutely incompatible therewith. It was therefore essential to supplement physical theory as more or less incompletely stated and understood by actual experiment.

The field of force revealed by agitating paper strewn with magnetic dust over the poles of a magnet is, we may say, a *statical* field, and can only have distant analogies with the *changing* field formed in viscid protoplasm, differentiated into strands and medium, the former more permeable, the latter less permeable, clearly, to the forces involved. To obtain a closer analogy I suspend magnetic dust in a viscid liquid (balsam, glycerine, melted jelly), and place the mixture in a trough or spread it on a plate above the poles of one or more electro-magnets, or their mere cores of soft iron. We obtain in the apparatus a thin axial section of such a field as would be given by *detached* magnetic poles; and with these arrangements I have obtained many variants from the text-book figures.

In any mixture the magnetic particles sort themselves out into what we may term material '*chains of force*,' following the directions of the lines of force and containing within them more of these lines than the relatively impermeable medium. Such chains of force may be deflected by currents, gravity, &c., and still carry within them a proportion of their lines of force not much diminished in the conditions of the experiment; for their elongation is of a much lower order than the ratio of the permeability of their material to that of the medium. The more important variants, comparable to the achromatic figures, of the cell realise many of the very conditions which have been regarded as incompatible with a dual force. They are illustrated by photographs of the magnetic fields compared with analogous cytoplasmic fields.

Variant 1.—In an unlimited magnetic field of two unlike poles all the lines of force tend to meet, and are concave to the interpolar axis. On limiting the field by a permeable boundary, such as an oval vignette mask of soft iron, the outer rays straighten out, or even become convex to the interpolar axis, and turn their backs on the rays joining the poles. In this way we get a closer approximation to the differentiation of the cell-figure into a dumbell, with circumpolar asters and interpolar spindle. From this we may infer that the Hautschicht of the cell is permeable to the force in operation (the nuclear wall appears to be also permeable).

Variant 2.—If the magnetising force be sufficiently intense to overcome the viscidity of the medium, the chains of force do not retain their primitive even distribution; but the interpolar chains move laterally towards the axis, becoming denser as they do so: like all movable conductors, they tend to place themselves in the most intense portion of the field. In this way they give an additional differentiation into spindle and asters, leaving on either side of the spindle a clear space comparable to what has been termed 'Bütschli's space' by Rhumbler.

Variant 3.—If our plate be slowly rotated over the poles the chains become spiral, or, more accurately, sigmoid—$\int$-shaped; this would be the section of an ovoid of revolution with spiral poles, such as were first figured by Mark in the segmentation of the slug (*Limax*). Such figures may be fixed if the medium be melted jelly or balsam.

Variant 4.—Even in the published figures formed on paper the material chains of force are frequently seen to anastomose—an impossibility for the *lines* of force in a uniform medium. Owing to the peculiar properties of these chains they often interlace in viscid media towards the minor axis of the figure; *i.e.*, they cross at slightly different levels. The less permeable the medium to the force, the less

will be the induction, and the more chance there is of such interlacings. Their presence in cell-figures has been a great difficulty on all interpretations.

Variant 5.—The existence of 3-asters has been another difficulty. A fair 3-aster is obtained by arranging unlike poles at the base of an obtuse-angled triangle and a core at its vertex. With chains of greater or a medium of lesser permeability the relative distances would be more nearly equalised.

Variant 6.—If we alternate two unlike poles and two cores we obtain a 4-aster, with the centres connected by consecutive spindles and a cross-spindle connecting the unlike poles. Such figures are not uncommon in the literature of the dividing cell.

Other variants are shown and compared with their cytoplasmic analogues.

Leduc has shown that centres of greater and of less concentration respectively in a solution give rise to diffusion fields of force, and that like centres of concentration (as might have been deduced *à priori*) behave as 'like' electric or magnetic poles, while only 'unlike' centres give the spindle figure. As it has been shown (notably by Vejdovský) that the diffusion phenomena in the cell are similar in both centres, the force producing the dumbell field cannot possibly be that of diffusion.

We may call *all the forces* at work in a cell undergoing division 'karyokinetic *forces*.' But the special force to which the cellular field is due cannot be termed 'karyokinetic force' in the singular, because it is operative while the nuclear wall is still intact; and the nuclear contents only become affected thereby after the wall has disappeared and the nucleus has lost its independence. We may distinguish the force here discussed as 'cytokinetism' or 'mitokinetism.' It is certainly not magnetism, since the poles are isolated; and very possibly it is distinct from statical electricity.

4. *Demonstration of Cytoplasmic Figures in Segmenting Eggs of Rynchelmis (Prof. Vejdovsky). By* Professor MARCUS HARTOG.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—DOUGLAS W. FRESHFIELD, F.R.G.S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

On Mountains and Mankind.

A GEOGRAPHER or traveller who has been called upon to preside over the meetings of our Section of the British Association may be excused for feeling some hesitation as to the character he shall give to the Address which custom compels him to deliver. He cannot but be aware that his audience, while it includes not a few experts, probably far better qualified than himself to take the Chair, is composed mainly of those whose concern in Geography can only be a general and occasional one.

To compose a summary of the geographical events of the year would be a simple and obvious expedient, were I not conscious that in this I have been forestalled by the indefatigable President of the Royal Geographical Society. To consider the progress of geography, during, say, the last quarter of a century, might be instructive to 'the general.' On the other hand, on his special subject your President may possibly be able to add something to the common stock by way of observation or suggestion.

Bearing in mind the, from the point of view of posterity, almost excessive energy with which the nineteenth century carried on the exploration of the globe, narrowing in every direction the field left to our explorations and our imaginations, 1904 may so far be counted as an 'annus mirabilis' in the annals of Geography. We have seen the successful return, if not as yet to our own shores, to safe seas, of the most important expedition ever sent South Polewards. In the success obtained by Captain Scott and his comrades, we have welcomed a full justification of the course taken in putting the supreme command and direction of the undertaking in the hands of an officer of His Majesty's Navy. 'England expects every man to do his duty,' and I will not indulge in hyperbolical praise, which must be distasteful to men who have shown in trying circumstances the daring, the cheerfulness, and the resourcefulness which we are accustomed to associate with the British Navy. We have every reason to expect that the results obtained by the energetic and capable men of science attached to the expedition will be of wide bearing and interest, but to attempt to estimate them to-day would be obviously premature.

The current year has been distinguished by a, perhaps, even more remarkable geographical event. His Majesty's Government, not satisfied with the laurels it has won in the Antarctic, has embarked on a second geographical adventure on a larger scale and at a far greater cost (which, however, will presumably be borne by India). It has sent forth a Gold Medallist of the Royal Geographical Society, Colonel Younghusband, with a numerous escort, to reach the forbidden capital of Tibet. The saffron-vested monks on the 'golden terraces' of the Pota La have

seen the glimmer of British bayonets on the horizon, and the castle-palaces of Lhasa will, we hope, open to the military explorer their mysterious halls, hitherto known to us best by the descriptions of that entertaining traveller, my friend Chandra Das.

But the fruits of these great expeditions are not yet ripe. I must leave them to be plucked by my successors. I do so with regret, for I should have listened with a peculiar interest to an account of the fascinating land, over whose peaks and pastures I lately gazed from the Pisgah heights of the Jonsong La.

To review the progress of Geography during the last twenty-five years, the time that has passed since I first joined the Council of the Royal Geographical Society, is tempting. The retrospect would on the whole be encouraging. The past quarter of a century, if not an era of the most extensive discoveries, has been an era of profitable occupation—I mean profitable in the scientific and not in the commercial sense, though the two are frequently connected—of the ground seized by the great pioneers in Africa, in the backlands of North America, and elsewhere. And when we come to consider the manner in which the results of modern exploration are recorded, what an advance we find! Compare the geographical publications of Great Britain in 1880 and 1904; take the most conspicuous instance, those of the Royal Geographical Society at the two periods. Consider the way in which our lectures and literature are now illustrated by the aid of photography, new processes, and the lantern. 'Petermann's Mitteilungen' was for long the one first-rate geographical magazine in Europe. We have now, as we ought to have had long before, a Journal that rivals it.

Take a wider survey. Look at maps, beginning with the Ordnance Survey. Compare the last issues of the one-inch maps, with all the advantages of colour-printing, over their doubtless (except as to roads) accurate, but far less intelligible predecessors. Consider the maps private firms, Messrs. Bartholomew and Messrs. Stanford, have provided us with; note the new editions of 'Murray's Guides.'

The correction and completion of maps by new explorations is always desirable. But it is even more important that a sound system for the delineation of natural features should be adopted both for Government surveys and general maps. I begin to look forward to a time when glaciers will no longer be represented, as they were on the early Indian and Caucasian surveys, without their heads or tails—that is, without either their névés or their moraine-cloaked lower portions or with rivers rising above them and flowing through them. In time, perhaps, every closet cartographer will recognise that glaciers do not lie along the tops of lofty ridges, but descend into valleys. In these matters I have had many an arduous struggle. It is cruel that a poor man should be set to delineate snow mountains who has never seen one, and when 'a week at lovely Lucerne' can be had for *5l. 5s.* it is inexcusable.

In my schooldays there was an exercise of memory known to us by the contemptuous appellation of 'Jog,' which boys and masters united to depreciate and despise. This sentiment is now confined to a few elderly generals and head-masters. Geography flourishes as a branch of science under the august shadow of the elder Universities. At Oxford we have produced Mr. Mackinder and Dr. Herbertson, Mr. Grundy, Mr. Hogarth, Mr. Beazley. We have started a school of Geography and a school of Geographers. At Cambridge a Board of Geographical Studies has been established. I may quote what Sir C. Markham said three months ago:—

'The staff of the new geographical school at Cambridge will consist, instead of one reader, of several lecturers and teachers, who will cover the various departments of the science. A diploma in geography will be granted as at Oxford. But Cambridge goes a step further than Oxford, by introducing geography into the examination for the B.A. degree. The importance of according geography such a position in the studies of the Universities must be evident to all, and must be specially gratifying to those who, for over thirty years, have fought hard, amid much discouragement, to have geography recognised as a University subject. It will be interesting to see how the Board of Geographical Studies at Cambridge will draw up the detailed regulations for the degree and the diploma, what steps

will be taken to secure a competent staff to cover the whole field of our science, and especially to train young University men for practical work in the field. We have every reason to expect that the results will prove satisfactory.

'The Geographical Association of Teachers, of which Mr. Mackinder and Dr. Herbertson are active members, is doing much to enlighten teachers with regard to the capabilities of the subject, to raise its standard, and to introduce improved methods of teaching. An interesting and useful conference was held last winter at the Chelsea Polytechnic, under its auspices, and in connection with the Conference there was an excellent exhibition of appliances used in teaching geography, the usefulness of which was increased by sending it to various provincial centres.'

In primary schools many teachers are furnishing excellent instruction, and are instructing themselves in the handbooks provided by our friends Dr. Mill and Mr. Chisholm and others. In the higher branches of education the problems of scientific geography are studied, and teachers are encouraged to develop the geographical aspects of other subjects, such as archæology, history, commerce, colonisation on the one hand, botany and natural history on the other. We have moved forwards and upwards, but do not let us flatter ourselves that we have as yet reached any considerable eminence. Probably many more of our countrymen can read a map in this generation than could in the last. A small percentage, I am glad to notice, are not hopelessly bewildered even by contour lines.

We are learning our geographical alphabet. In time we may, as a nation, be able to read and to understand what we read. We shall recognise that ability to use a map and judge ground is a considerable safeguard against waste of life and disasters in war, and that an acquaintance with the features of the earth's surface and geographical distribution is an invaluable help to a nation in the commercial rivalries and struggles of peace.

When the question of establishing Geography at Oxford was being discussed, Dr. Jowett (who had himself somewhere in the fifties suggested the erection of a Geographical Chair) asked me if I believed Geography could be taught so 'as to make men think.' We should, I believe, 'think imperially' to more purpose if we also took pains 'to think geographically.' But I will not detain you and use up my time by going in any detail into the progress of Geography. I might find myself only repeating what others have said better. And as to one important branch, perhaps the most important branch, geographical education, on which I addressed this Section at Birmingham some fifteen years ago, I feel myself debarred by the fact that the Association has now a Section specially devoted to Education.

I have determined on the whole, therefore, to run the risk of wearying some of my listeners by inviting your attention to the place in Geography of the natural objects which have had for me through life the greatest and most enduring attraction. I propose to talk about mountains, their place in Nature, and their influence, both spiritual and material, on mankind.

We have all of us seen hills, or what we call hills, from the monstrous protuberances of the Andes and the Himalaya to such puny pimples as lie about the edges of your fens. Next to a waterfall, the first natural object (according to my own experience) to impress itself on a child's mind is a hill, some spot from which he can enlarge his horizon. Hills, and still more mountains, attract the human imagination and curiosity. The child soon asks, 'Tell me, how were mountains made?' a question easier to ask than to answer, which occupied the lifetime of the father of mountain science, De Saussure. But there are mountains and mountains. Of all natural objects the most impressive is a vast snowy peak rising as a white island above the waves of green hills—a fragment of the arctic world left behind to commemorate its past predominance—and bearing on its broad shoulders a garland of the Alpine flora that has been destroyed on the lower ground by the rising tide of heat and drought that succeeded the last glacial epoch. Midsummer snows, whether seen from the slopes of the Jura or the plains of Lombardy, above the waves of the Euxine or through the glades of the tropical forests of Sikhim, stir men's imaginations and rouse their curiosity. Before, however, we turn to consider some of the physical aspects of mountains,

I shall venture, speaking as I am here to a literary audience, and in a University town, to dwell for a few minutes on their place in literature—in the mirror that reflects in turn the mind of the passing ages. For Geography is concerned with the interaction between man and Nature in its widest sense. There has been recently a good deal of writing on this subject—I cannot say of discussion, for of late years writers have generally taken the same view. That view is that the love of mountains is an invention of the nineteenth century, and that in previous ages they had been generally looked on either with indifference or positive dislike, rising in some instances to abhorrence. Extreme examples have been repeatedly quoted. We have all heard of the bishop who thought the devil was allowed to put in mountains after the fall of man; of the English scribe in the tenth century who invoked 'the bitter blasts of glaciers and the Pennine host of demons' on the violators of the charters he was employed to draft. The examples on the other side have been comparatively neglected. It seems time they were insisted on.

The view I hold firmly, and which I wish to place before you to-day, is that this popular belief that the love of mountains is a taste, or, as some would say, a mania, of advanced civilisation, is erroneous. On the contrary, I allege it to be a healthy, primitive, and almost universal human instinct. I think I can indicate how and why the opposite belief has been fostered by eminent writers. They have taken too narrow a time-limit for their investigation. They have compared the nineteenth century not with the preceding ages, but with the eighteenth. They have also taken too narrow a space-limit. They have hardly cast their eyes beyond Western Europe. Within their own limits I agree with them. The eighteenth century was, as we all know, an age of formality. It was the age of Palladian porticoes, of interminable avenues, of formal gardens and formal style in art, in literature, and in dress. Mountains, which are essentially romantic and Gothic, were naturally distasteful to it. The artist says 'they will not compose,' and they became obnoxious to a generation that adored composition, that thought more of the cleverness of the artist than of the aspects of Nature he used as the material of his work. There is a great deal to be said for the century; it produced some admirable results. It was a contented and material century, little stirred by enthusiasms and aspirations and vague desires. It was a phase in human progress, but in many respects it was rather a reaction than a development from what had gone before. Sentiment and taste have their tides like the sea, or, we may here perhaps more appropriately say, their oscillations like the glaciers. The imagination of primitive man abhors a void, it peoples the regions it finds uninhabitable with aery sprites; with 'Pan and father Sylvanus and the sister Nymphs,' it worships on high places and reveres them as the abode of Deity. Christianity came and denounced the vague symbolism and personification of Nature in which the pagan had recognised and worshipped the Unseen. It found the objects of its devotion not in the external world but in the highest moral qualities of man. Delphi heard the cry 'Great Pan is dead!' But the voice was false. Pan is immortal. Every villager justifies etymology by remaining more or less of a pagan. Other than villagers have done the same. The monk driven out of the world by its wickedness fell in love with the wilderness in which he sought refuge, and soon learnt to give practical proof of his love of scenery by his choice of sites for his religious houses. But the literature of the eighteenth century was not written by monks or countrymen, or by men of world-wide curiosity and adventure like the Italians of the Renaissance or our Elizabethans. It was the product of a practical common-sense epoch which looked on all waste places, heaths like Hindhead, or hills like the Highlands, as blemishes in the scheme of the universe, not having yet recognised their final purpose as golf links or gymnasiums. Intellectual life was concentrated in cities and courts, it despised the country. Books were written by townsmen, dwellers in towns which had not grown into vast cities, and whose denizens therefore had not the longing to escape from their homes into purer air that we have to-day. They abused the Alps frankly. But all they saw of them was the comparatively dull carriage passes, and these they saw at the worst time of year. Hastening to Rome for

Easter, they traversed the Maurienne while the ground was still brown with frost and patched untidily with half-melted snowdrifts. It is no wonder that Gray and Richardson, having left spring in the meadows and orchards of Chambéry, grumbled at the wintry aspect of Lanslebourg.

That at the end of the eighteenth century a literary lady of Western Europe preferred a Paris gutter to the Lake of Geneva is an amusing caricature of the spirit of the age that was passing away, but it is no proof that the love of mountains is a new mania, and that all earlier ages and peoples looked on them with indifference or dislike. Wordsworth and Byron and Scott in this country, Rousseau and Goethe, De Saussure and his school abroad broke the ice, but it was the ice of a winter frost, not of a glacial period.

Consider for a moment the literature of the two peoples who have most influenced European thought—the Jews and the Greeks. I need hardly quote a book that before people quarrelled over education was known to every child—the Bible. I would rather refer you to a delightful poem in rhyming German verse written in the seventeenth century by a Swiss author, Rebman, in which he relates all the great things that happened on mountains in Jewish history: how Solomon enjoyed his Sommerfrische on Lebanon, and Moses and Elias both disappeared on mountain tops; how kings and prophets found their help among the hills; how closely the hills of Palestine are connected with the story of the Gospels.

Consider, again, Greece, where I have just been wandering. Did the Greeks pay no regard to their mountains? They seized eagerly on any striking piece of hill scenery and connected it with a legend or a shrine. They took their highest mountain, broad-backed Olympus, for the home of the gods; their most conspicuous mountain, Parnassus, for the home of poetry. They found in the cliffs of Delphi a dwelling for their greatest oracle and a centre for their patriotism. One who has lately stood on the top of Parnassus and seen the first rays of the sun as it springs from the waves of the Ægean strike its snows, while Attica and Bœotia and Eubœa still lay in deep shadow under his feet, will appreciate the famous lines of Sophocles, which I will not quote, as I am uncertain how you may pronounce Greek in this University. You may remember, too, that Lucian makes Hermes take Charon, when he has a day out from Hell, to the twin-crested summit, and show him the panorama of land and sea, of rivers and famous cities. The Vale of Tempe, the deep gap between Olympus and Ossa, beautiful in its great red cliffs, fountains, and spreading plane-trees, was part of a Roman's classical tour. The superb buttresses in which Taygetus breaks down on the valley of the Eurotas were used by the Spartans for other purposes besides the disposal of criminals and weakly babies. The middle regions—the lawns above the Langada Pass, 'virginibus bacchata Lacænis Taygeta'—are frequented to this day as a summer resort by Spartan damsels. The very top, the great rock that from a height of 8,000 feet looks down through its woods of oaks and Aleppo pines on the twin bays of the southern sea, is a place of immemorial pilgrimages. It is now occupied by a chapel framed in a tiny court, so choked with snow at the beginning of June that I took the ridge of the chapel roof for a dilapidated stoneman. I have no time to-day to look for evidence in classical literature, to refer to the discriminating epithets applied in it to mountain scenes.

A third race destined apparently to play a great part in the world's history—the Japanese—are ancient mountain lovers. We are all aware that Fusiyama to the Japanese is (as Ararat to the Armenians) a national symbol; that its ascent is constantly made by bands of pilgrims; that it is depicted in every aspect. Those who have read the pleasant book of Mr. Watson, who, as English chaplain for some years at Tokio, had exceptional opportunities of travel in the interior, will remember how often he met with shrines and temples on the summits of the mountains, and how he found pilgrims who frequented them in the belief that they fell there more readily into spiritual trances. The Japanese Minister, when he attended Mr. Watson's lecture at the Alpine Club, told us that his countrymen never climbed mountains without a serious—that is to say, a religious—object.

India and China would add to my evidence had I knowledge and time enough

to refer to their literature. I remember Tennyson pointing out to me in a volume of translations from the Chinese a poem, written about the date of King Alfred, in praise of a picture of a mountain landscape. But I must return to the sixteenth and seventeenth centuries in Europe; I may go earlier—even back to Dante. His allusions to mountain scenery are frequent; his Virgil had all the craft of an Alpine rock-climber. Read Leonardo da Vinci's 'Notes,' Conrad Gesner's 'Ascent of Pilatus;' study the narratives of the Alpine precursors Mr. Coolidge has collected and annotated with admirable industry in the prodigious volume he has recently brought out.

It is impossible for me here to multiply proofs of my argument, to quote even a selection from the passages that show an authentic enthusiasm for mountains that may be culled from writers of various nations prior to A.D. 1600. I must content myself with the following specimens, which will probably be new to most of my hearers.

Benoît Marti was a professor of Greek and Hebrew at Bern, and a friend of the great Conrad Gesner (I call him great, for he combined the qualities of a man of science and a man of letters, was one of the fathers of botany as well as of mountaineering, and was, in his many-sidedness, a typical figure of the Renaissance). Marti, in the year 1558 or 1559, wrote as follows of the view from his native city:—

'These are the mountains which form our pleasure and delight' (the Latin is better—'deliciæ nostræ, nostrique amores') 'when we gaze at them from the higher parts of our city and admire their mighty peaks and broken crags that threaten to fall at any moment. Here we watch the risings and settings of the sun and seek signs of the weather. In them we find food not only for our eyes and our minds but also for our bellies;' and he goes on to enumerate the dairy products of the Oberland and the happy life of its population. I quote again this good man: 'Who, then, would not admire, love, willingly visit, explore, and climb places of this sort? I assuredly should call those who are not attracted by them mushrooms, stupid, dull fishes, and slow tortoises' ('fungos, stupidos insulsos pisces, lentosque chelones'). 'In truth, I cannot describe the sort of affection and natural love with which I am drawn to mountains, so that I am never happier than on the mountain crests, and there are no wanderings dearer to me than those on the mountains.' 'They are the theatre of the Lord, displaying monuments of past ages, such as precipices, rocks, peaks and chasms, and never-melting glaciers;' and so on through many eloquent paragraphs.

I will only add two sentences from the preface to Simler's 'Vallesiæ et Alpium Descriptio,' first published in 1574, which seem to me a strong piece of evidence in favour of my view:—'In the entire district, and particularly in the very lofty ranges by which the Vallais is on all sides surrounded, wonders of Nature offer themselves to our view and admiration. With my countrymen many of them have through familiarity lost their attraction; but foreigners are overcome at the mere sight of the Alps, and regard as marvels what we through habit pay no attention to.'

Mr. Coolidge, in his singularly interesting footnotes, goes on to show that the books that remain to us are not isolated instances of a feeling for mountains in the age of the Renaissance. The mountains themselves bear, or once bore, records even more impressive. Most of us have climbed to the picturesque old castle at Thun and seen beyond the rushing Aar the green heights of the outposts of the Alps, the Stockhorn, and the Niesen. Our friend Marti, who climbed the former peak about 1558, records that he found on the summit 'tituli, rythmi, et proverbia saxis inscripta unà cum imaginibus et nominibus auctorum. Inter alia cujusdam docti et montium amœnitate capti observare licebat illud:

'Ο τῶν ὄρων ἔρως ἄριστος.'

'The love of mountains is best.' In those five words some Swiss professor anticipated the doctrine of Ruskin and the creed of Leslie Stephen, and of all men who have found mountains the best companions in the vicissitudes of life.

In the annals of art it would be easy to find additional proof of the attention paid by men to mountains three to four hundred years ago. The late Josiah Gilbert, in a charming but too little-known volume, 'Landscape in Art,' has shown how many great painters depicted in their backgrounds their native hills. Titian is the most conspicuous example.

It will perhaps be answered that this love of mountains led to no practical result, bore no visible fruit, and therefore can have been but a sickly plant. Some of my hearers may feel inclined to point out that it was left to the latter half of the nineteenth century to found Climbers' Clubs. It would take too long to adduce all the practical reasons which delayed the appearance of these fine fruits of peace and an advanced civilisation. I am content to remind you that the love of mountains and the desire to climb them are distinct tastes. They are often united, but their union is accidental not essential. A passion for golf does not necessarily argue a love of levels. I would suggest that more outward and visible signs than is generally imagined of the familiar relations between men and mountains in early times may be found. The choicest spots in the Alpine region—Chamonix, Engelberg, Disentis, Einsiedeln, Pesio, the Grande Chartreuse—were seized on by recluses; the Alpine Baths were in full swing at quite an early date. I will not count the Swiss Baden, of which a geographer, who was also a Pope, Æneas Silvius (Pius II.) records the attractions, for it is in the Jura, not the Alps; but Pfäfers, where wounded warriors went to be healed, was a scene of dissipation, and the waters of St. Moritz were vaunted as superseding wine. I may be excused, since I wrote this particular passage myself a good many years ago, for quoting a few sentences bearing on this point from 'Murray's Handbook to Switzerland.' In the sixteenth century fifty treatises dealing with twenty-one different resorts were published. St. Moritz, which had been brought into notice by Paracelsus (died 1541), was one of the most famous baths. In 1501 Matthew Schinner, the famous Prince Bishop of Sion, built 'a magnificent hotel' at Leukerbad, to which the wealthy were carried up in panniers on the back of mules. Brieg, Gurnigel, near Bern, the Baths of Masino, Tarasp, and Pfäfers were also popular in early times. Leonardo da Vinci mentions the baths of Bormio, and Gesner went there.

It is not, however, with the emotional influences or the picturesque aspect of mountains that science concerns itself, but with their physical examination. If I have lingered too long on my preamble I can only plead as an excuse that a love of one's subject is no bad qualification for dealing with it, and that it has tempted me to endeavour to show you grounds for believing that a love of mountains is no modern affectation, but a feeling as old and as widespread as humanity.

Their scientific investigation has naturally been of comparatively modern date. There are a few passages about the effects of altitude, there are orographical descriptions more or less accurate in the authors of antiquity. But for attempts to explain the origin of mountains, to investigate and account for the details of their structure, we shall find little before the notes of Leonardo da Vinci, that marvellous man who combined, perhaps, more than anyone who has ever lived the artistic and the scientific mind. His ascent of Monte Boso about 1511, a mountain which may be found under this name on the Italian Ordnance map on the spur separating Val Sesia and the Biellese, was the first ascent by a physical observer. Gesner with all his mountain enthusiasm found a scientific interest in the Alps mainly if not solely in their botany.

The phenomenon which first drew men of science to Switzerland was the Grindelwald glaciers—'miracles of Nature' they called them. Why these glaciers in particular, you may ask, when there are so many in the Alps? The answer is obvious. Snow and ice on the 'mountain tops that freeze' are no miracle. But when two great tongues of ice were found thrusting themselves down among meadows and corn and cottages, upsetting barns and covering fields and even the marble quarries from which the citizens of Bern dug their mantelpieces, there was obviously something outside the ordinary processes of Nature, and therefore miraculous.

Swiss correspondents communicated with our own Royal Society the latest news as to the proceedings of these unnatural ice-monsters, while the wise men of Zürich and Bern wrote lectures on them. Glacier theories began. Early in the eighteenth century Hottinger, Cappeller, Scheuchzer, that worthy man who got members of our Royal Society to pay for his pictures of flying dragons, contributed their quota of crude speculation. But it was not till 1741 that Mont Blanc and its glaciers were brought into notoriety by our young countrymen, Pococke and Windham, and became an attraction to the mind and an object to the ambition of the student whose name was destined to be associated with them. Horace Benedict de Saussure, born of a scientific family, the nephew of Bonnet, the Genevese botanist and philosopher, who has become known to the world as a mountaineer and the climber of Mont Blanc, came twenty years later. In truth he was far more of a mountain traveller and a scientific observer, a geological student, than a climber. When looking at his purple silk frock-coat (carefully preserved in his country house on the shore of the Lake of Geneva), one realises the difference between the man who climbed Mont Blanc in that garment and the modern gymnast, who thinks himself *par excellence* the mountaineer.

De Saussure did not confine himself to Savoy or to one group, he wandered far and wide over the Alpine region, and the four volumes of his 'Voyages' contain, besides the narratives of his sojourn on the Col du Géant and ascent of Mont Blanc, a portion of the fruit of these wanderings.

The reader who would appreciate De Saussure's claim as the founder of the Scientific Exploration of Mountains must, however, be referred to the List of Agenda on questions calling for investigation placed at the end of his last volume. They explain the comparative indifference shown by De Saussure to the problems connected with glacial movement and action. His attention was absorbed in the larger question of earth-structure, of geology, to which the sections exposed by mountains offered, he thought, a key; he was bitten by the contemporary desire for 'A Theory of the Earth,' by the taste of the time for generalisations for which the facts were not always ready. At the same time, his own intellect was perhaps somewhat deficient in the intuitive faculty; the grasp of the possible or probable bearing of known facts by which the greatest discoverers suggest theories first and prove them afterwards.

The school of De Saussure at Geneva died out after having produced Bourrit, the tourist who gloried in being called the Historian of the Alps, a man of pleasant self-conceit and warm enthusiasm, and De Luc, a mechanical inventor, who ended his life as reader to Queen Charlotte at Windsor, where he flits across Miss Burney's pages as the friend of Herschel at Slough and the jest of tipsy Royal Dukes. Oddly enough, the first sound guess as to glacier movement was made by one Bordier, who had no scientific pretensions. I reprinted many years ago the singular passage in which he compared glacier ice to 'cire amollie,' soft wax, 'flexible et ductile jusqu'à un certain point,' and described it as flowing in the manner of liquids (*Alp. J.*, ix. 327). He added this remarkable suggestion foreshadowing the investigations of Professor Richter and M. Forel: 'It is very desirable that there should be at Chamonix someone capable of observing the glaciers for a series of years and comparing their advance and oscillations with meteorological records.' To the school of Geneva succeeded the school of Neuchatel, Desor and Agassiz; the feat of De Saussure was rivalled on the Jungfrau and the Finsteraarhorn by the Meyers of Bern. They in turn were succeeded by the British school, Forbes and Tyndall, Reilly and Wills, in 1840-60.

In 1857 the Alpine Club was founded in this country. In the half-century since that date the nations of Western Europe have emulated one another in forming similar bodies, one of the objects of which has been to collect and set in order information as to the mountains and to further their scientific as well as their geographical exploration.

What boulders, or rather pebbles, can we add to the enormous moraine of modern Alpine literature—a moraine the lighter portions of which it is to be hoped for the sake of posterity that the torrent of Time may speedily make away with?

For fifty years I have loved and at frequent intervals wandered and climbed in the Alps. I have had something of a grand passion for the Caucasus. I am on terms of visiting acquaintance with the Pyrenees and the Himalaya, the Apennines and the Algerian Atlas, the mountains of Greece, Syria, Corsica, and Norway. I will try to set in order some observations and comparisons suggested by these various experiences.

As one travels east from the Atlantic through the four great ranges of the Old World the peaks grow out not only in absolute height but also in abruptness of form, and in elevation above the connecting ridges. The snow and ice region increases in a corresponding manner. The Pyrenees have few fine rockpeaks except the Pic du Midi d'Ossau ; its chief glacier summits, the Vignemale, Mont Perdu, the Maladetta correspond to the Titlis or the Buet in the Alps. The peaks of the Alps are infinite in their variety and admirable in their clear-cut outlines and graceful curves. But the central group of the Caucasus, that which culminates in Dykhtau, Koshtantau, and Shkara, 17,000 feet summits (Koshtantau falls only 120 feet below this figure) has even more stately peaks than those that cluster round Zermatt.

Seek the far eastern end of the Himalaya, visit Sikhim, and you will find the scale increased; Siniolchum, Jannu, and Kangchenjunga are all portentous giants. To put it at a low average figure, the cliffs of their final peaks are half as high again as those of Monte Rosa and the Matterhorn.

In all these chains you will find the same feature of watersheds or partings lying not in but behind the geological axis, which is often the line of greatest peak elevation. This is the case in the Alps at the St. Gothard, in the Caucasus for some forty miles west of the Dariel Pass, in the Himalaya, in Sikhim and Nepal, where the waters flowing from the Tibetan plateau slowly eat their way back behind Kangchenjunga and the Nepalese snows. The passes at their sources are found consequently to be of the mildest character, hills 'like Wiltshire Downs,' is the description given by a military explorer. It needs no great stretch of geological imagination to believe in the cutting back of the southern streams of Sikhim or the Alps, as for instance at the Maloya, but I confess that I cannot see how the gorges of Ossetia, clefts cut through the central axis of the Caucasus, can be ascribed mainly to the action of water.

I turn to the snow and ice region. Far more snow is deposited on the heights of the Central Caucasus and the Eastern Himalaya than on the Alps. It remains plastered on their precipices, forming hanging glaciers everywhere of the kind found on the northern, the Wengern Alp, face of the Jungfrau. Such a peak as the Weisshorn looks poor and bare compared with Tetnuld in the Caucasus or Siniolchum in the Himalaya. The plastered sheets of snow between their great bosses of ice are perpetually melting, their surfaces are grooved, so as to suggest fluted armour, by tiny avalanches and runnels.

In the Aletsch glacier the Alps have a champion with which the Caucasus cannot compete; but apart from this single exception the Caucasian glaciers are superior to the Alpine in extent and picturesqueness. Their surfaces present the features familiar to us in the Alps—icefalls, moulins, and earth-cones.

In Sikhim, on the contrary, the glaciers exhibit many novel features due no doubt mainly to the great sun-heat. In the lower portion their surface is apt to be covered with the *débris* that has fallen from the impending cliffs, so that little or no ice is visible from any distance. In the region below the névé there are very few crevasses, the ice heaves itself along in huge and rude undulations, high gritty mounds, separated by hollows often occupied by yellow pools which are connected by streams running in little icy ravines; a region exceptionally tiresome, but in no way dangerous to the explorer. In steep places the Alpine icefall is replaced by a feature I may best compare with a series of earth-pillars such as are found near Evolena and elsewhere, and are figured in most text-books. The ice is shaped into a multitude of thin ridges and spires, resembling somewhat the Nieves Penitentes of the Andes—though formed in a different material.

Great sun-heat acting on surfaces unequally protected, combined in the latter

case with the strain of sudden descent, is no doubt the cause of both phenomena. Generally the peculiarities of the great glaciers of Kangchenjunga may be attributed to a vertical sun, which renders the frozen material less liable to crack, less rigid, and more plastic.

A glacier, as a rule, involves a moraine. Now moraines are largely formed from the material contributed by subaerial denudation, in plain words by the action of heat and cold and moisture on the cliffs that border them. It is what falls on a glacier, not that which it falls over, that mainly makes a moraine. The proof is that the moraines of a glacier which flows under no impending cliffs are puny compared with those of one that lies beneath great rockwalls.

Take, for example, the Norwegian glaciers of the Jostedals Brae and compare them with the Swiss. The former, falling from a great névé plain or snowfield, from which hardly a crag protrudes, are models of cleanliness. I may cite as examples the three fascinating glaciers of the Olden Valley. The Rosenlaui Glacier in Switzerland owed the cleanliness which gave it a reputation fifty years ago, before its retirement from tourists' tracks, to a similar cause—a vast snow-plateau, the Wetterkessel.

One peculiarity very noticeable both in the Himalaya and the Caucasus I have never found satisfactorily accounted for. I refer to the long grassy trenches lying between the lateral moraine and the hillside, which often seem to the mountain explorer to have been made by Providence to form grass paths for his benefit. They may possibly be due to the action of torrents falling from the hillside, which, meeting the moraine and constantly sweeping along its base, undermine it and keep a passage open for themselves. There are remarkable specimens of this formation on both sides of the Bezingi Glacier, in the Caucasus, and on the north side of the Zemu Glacier, in Sikhim.

Water is one of the greatest features in mountain scenery. In Norway it is omnipresent. In this respect Scandinavia is a region apart, the streams of the more southern ranges are scanty compared with those of a region where the snow-fall of two-thirds of the year is discharged in a few weeks. Greece stands at the opposite pole. By what seems a strange perversity of Nature, its slender streams are apt to disappear underground, to reissue miles away in the great fountains that gave rise to so many legends. Arcadia is, for the most part, a dry upland, sadly wanting in the two elements of pastoral scenery, shady groves, and running brooks.

The Alps are distinguished by their subalpine lakes—

> 'Anne lacus tantos; te, Lari maxime, teque
> Fluctibus et fremitu assurgens, Benace, marino?'

of Virgil. But perhaps even more interesting to the student are the lake basins that have been filled up, and thus suggest how similar lakes may have vanished at the base of other ranges.

I know no more striking walk to anyone interested in the past doings of glaciers than that along the ridge of the mighty moraine of the old glacier of Val d'Aosta, which sweeps out, a hill 500 feet high, known as 'La Serra,' from the base of the Alps near Ivrea into the plain of Piedmont. Enclosed in its folds still lies the Lago di Viverone; but the Dora has long ago cut a gap in the rampart and drained the rest of the enclosed space, filling it up with the fluvial deposit of centuries.

It is, however, the tarns rather than the great lakes of the Alps which have been the chief subjects of scientific disputation. Their distribution is curious. They are found in great quantity in the Alps and Pyrenees, hardly at all in the Caucasus, and comparatively rarely in the part of the Himalaya I am acquainted with.

A large-scale map will show that where tarns are most thickly dotted over the uplands the peaks rise to no great height above the ridges that connect them. This would seem to indicate that there has been comparatively little subaerial denudation in these districts, and consequently less material has been brought down to fill the hollows. Again, it is in gneiss and granitic regions that we find

tarns most abundant—that is, where the harder and more compact rocks make the work of streams in tapping the basins more lengthy. The rarity of tarns in the highlands behind Kanchenjunga, perhaps, calls for explanation. We came upon many basins, but, whether formed by moraines or true rock-basins, they had for the most part been filled up by alluvial deposits.

In my opinion, the presence of tarns must be taken as an indication that the portion of the range where they are found has until a comparatively recent date been under snow or ice. The former theory, still held, was that the ice scooped out their basins from the solid rock. I believe that it simply kept scoured pre-existing basins. The ice removed and the surrounding slopes left bare, streams on the one hand filled the basins with sediment, or, on the other, tapped them by cutting clefts in their rims. This theory meets, at any rate, all the facts I have observed, and I may point out that the actual process of the destruction of tarns by such action may be seen going on under our eyes in many places, notably in the glens of the Adamello group. Professor Garwood has lately employed his holidays in sounding many of the tarns of the St. Gotthard group, and his results, I understand, tend to corroborate the conclusions stated.

I desire here to reaffirm my conviction that snow and ice in the High Alps are conservative agents: that they arrest the natural processes of subaerial denudation; that the scouring work done by a glacier is insignificant compared with the hewing and hacking of frost and running water on slopes exposed to the open sky without a roof of névé and glacier.

The contrast between the work of these two agents was forced upon me many years ago while looking at the ground from which the Eiger Glacier had then recently retreated. The rocks, it is true, had had their angles rubbed off by the glacier, but through their midst, cut as by a knife, was the deep slit or gash made by the subglacial torrent. There is in the Alps a particular type of gorge, found at Rosenlaui, at the Lower Grindelwald Glacier, at the Kirchet above Meiringen, and also in the Caucasus, within the curves of old terminal moraines. It is obviously due to the action of the subglacial torrent, which cuts deeper and deeper while the ice above protects the sides of the cutting from the effects of the atmosphere.

One more note I have to make about glaciers. It has been stated that glaciers go on melting in winter. Water, no doubt, flows from under some of them, but that is not the same thing. The end of the Rosenlaui Glacier is dry in January; you can jump across the clear stream that flows from the Lower Grindelwald glacier. That stream is not meltings, but the issue of a spring which rises under the glacier and does not freeze. There is another such stream on the way to the Great Scheideck, which remains free when frost has fettered all its neighbours.

I should like to draw your attention before we leave glaciers to the systematic efforts that are being made on the Continent to extend our knowledge of their peculiarities. The subject has a literature of its own, and two Societies—one in France, one in other countries—have been constituted to promote and systematise further investigations, especially with regard to the secular and annual oscillations of the ice. These were initiated by the English Alpine Club in 1893, while I was its president. Subsequently, through the exertions of the late Marshall Hall, an enthusiast on the subject, an International Commission of Glaciers was founded, which has been presided over by Dr. Richter, M. Forel, and others; and more recently a French Commission has been created with the object of studying in detail the glaciers of the French Alps. A number of excellent reports have been published, embodying information from all parts of the globe. There has been, and is, I regret to say, very great difficulty in obtaining any methodical reports from the British possessions oversea. The subject does not commend itself to the departmental mind. Let us hope for improvement: I signalise the need for it. Of course, it is by no means always an easy matter to get the required measurements of retreat or advance in the glacial snout, when the glacier is situated in a remote and only casually visited region. Still, with good-will more might be done than has been. The periods of advance and retreat of glaciers appear to correspond to a certain extent throughout the globe. The middle of the last

century was the culmination of the last great advance. The general estimate of their duration appears to be half a century. The ice is now retreating in the Alps, the Caucasus, and the Himalaya, and I believe in North America. We live in a retrogressive period. The minor oscillation of advance which a few years ago gave hopes to those who, like myself, had as children seen the glaciers of Grindelwald and Chamonix at their greatest, has not been carried on.

Attempts are made to connect the oscillations of glaciers with periods of sunspots. They are, of course, connected with the rain or snow-fall in past seasons. But the difficulty of working out the connection is obvious.

The advance of the ice will not begin until the snows falling in its upper basin have had time to descend as ice and become its snout; in each glacier this period will vary according to its length, bulk, and steepness, and the longer the glacier is, the slower its lower extremity will be to respond. Deficiency in snowfall will take effect after the same period. It will be necessary, therefore, to ascertain (as has been done in a tragic manner on Mont Blanc by the recovery in the lowest portion of the Glacier des Bossons of the bodies of those lost in its highest snows) the time each glacier takes to travel, and to apply this interval to the date of the year with which the statistics of deposition of moisture are to be compared. If the glacier shows anything about weather and climate, it is past not contemporary weather it indicates.

Another point in which the Asiatic ranges, and particularly the Himalaya, differ from the Alps is in the frequency of snow avalanches, earthfalls, and mud-slides. These are caused by the greater deposition of snow and the more sudden and violent alternations of heat and cold, which lead to the splitting of the hanging ice and snows by the freezing of the water in their pores. I have noticed at a bivouac that the moment of greatest cold—about the rising of the morning star—is often hailed by the reports of a volley of avalanches.

The botanist may find much to do in working out a comparison of the flora of my four ranges. I am no botanist: I value flowers according, not to their rarity, but to their abundance, from the artist's, not the collector's, point of view. But it is impossible not to take interest in such matters as the variations of the gentian in different regions, the behaviour of such a plant as the little Edelweiss (once the token of the Tyrolese lover, now the badge of every Alp-trotter), which frequents the Alps, despises the Caucasus, reappears in masses in the Himalaya, and then, leaping all the isles of the tropics, turns up again under the snows of New Zealand. I may mention that it is a superstition that it grows only in dangerous places. I have often found it where cows can crop it; it covers acres in the Himalaya, and I believe it has been driven by cows off the Alpine pastures, as it is being driven by tourists out of the Alps altogether.

The Italian botanists, MM. Levier and Sommier, have given a vivid account of what they call the Makroflora of the Central Caucasus—those wild-flower beds, in which a man and horse may literally be lost to sight, the product of sudden heat on a rich and sodden soil composed of the vegetable mould of ages. Has any competent hand celebrated the Mikroflora of the highest ridges, those tiny, vivid forget-me-nots and gentians and ranunculuses that flourish on rock-island 'Jardins' like that of Mont Blanc, among the eternal snows, and enamel the highest rocks of the Basodano and the Lombard Alps? A comprehensive work on a comparison of mountain flora and the distribution of Alpine plants throughout the ranges of the Old World would be welcome. We want another John Ball. Allied to botany is forestry, and the influence of trees on rainfall, and consequently the face of the mountains, a matter of great importance, which in this country has hardly had the attention it deserves.

From these brief suggestions as to some of the physical features of mountains I would ask you to turn your attention to the points in which mankind come in contact with them, and first of all to History.

I fancy that the general impression that they have served as efficient barriers is hardly in accordance with facts, at any rate from the military point of view. Hannibal, Cæsar, Charles the Great, and Napoleon passed the Alps successfully. Hannibal, it is true, had some difficulty, but then he was handicapped with

elephants. The Holy Roman Emperors constantly moved forwards and backwards. Burgundy, as the late Mr. Freeman was never weary of insisting, lay across the Alps. So till our own day did the dominions of the House of Savoy. North Italy has been in frequent connection with Germany; it is only in my own time that the Alps have become a frontier between France and Italy. But questions of this kind might lead us too far. Let me suggest that some competent hand should compose a history of the Alpine passes and their famous passages, more complete than the treatises that have appeared in Germany. Mr. Coolidge, to whom we owe so much, has, in his monumental collection and reprint of early Alpine writers, just published, thrown great light on the extensive use of what I may call the by-passes of the Alps in early times. Will he not follow up his work by treating of the Great Passes? I may note that the result of the construction of carriage roads over some of them was to concentrate traffic; thus the Monte Moro and the Gries were practically deserted for commercial purposes when Napoleon opened the Simplon. The roads over the Julier and Maloya ruined the Septimer. Another hint to those engaged in tracing ancient lines of communication. In primitive times, in the Caucasus to-day, the tendency of paths is to follow ridges, not valleys. The motives are on the spot obvious—to avoid torrents, swamps, ravines, earthfalls, and to get out of the thickets and above the timber-line. The most striking example is the entrance to the great basin of Suanetia, which runs not up its river, the Ingur, but over a ridge of nearly 9,000 feet, closed for eight months in the year to animals.

From the military point of view mountains are now receiving great attention in Central Europe. The French, the Italians, the Swiss, the Austrians have extensive Alpine manœuvres every summer, in which men, mules, and light artillery are conveyed or carried over rocks and snow. Officers are taught to use maps on the spot, the defects in the official surveys are brought to light. It is not likely, perhaps, except on the Indian frontier, that British troops will have to fight among high snowy ranges. But I feel sure that any intelligent officer who is allowed to attend such manœuvres might pick up valuable hints as to the best equipment for use in steep places. Probably the Japanese have already sent such an envoy and profited by his experience.

A word as to maps, in which I have taken great interest, may be allowed me. The Ordnance maps of Europe have been made by soldiers, or under the supervision of soldiers. At home when I was young, it was dangerous to hint at any defects in our Ordnance sheets, for surveyors in this country are a somewhat sensitive class. Times have altered, and they are no longer averse from receiving hints and even help from unofficial quarters. Since the great surveys of Europe were executed, knowledge has increased so that every country has had to revise or to do over again its surveys. In three points that concern us there was great room for improvement—the delineation of the upper region as a whole, and the definition of snow and glaciers in particular, and in the selection of local names. In the two former the Federal Staff at Bern has provided us with an incomparable model. The number of local names known to each peasant is small, his pronunciation is often obscure, and each valley is apt to have its own set of names for the ridges and gaps that form its skyline. Set a stranger, speaking another tongue than the local *patois*, to question a herdsman, and the result is likely to be unsatisfactory. It has often proved so. The Zardezan is an odd transcription of the Gias del Cian of *patois*, the Gîte du Champ in French. The Grand Paradis is the last term an Aostan peasant would have used for the Granta Parei, the great screen of rock and ice of the highest mountain in Italy. The Pointe de Rosablanche was the Roesa Bianca, or white glacier. Monte Rosa herself, though the poet sees a reference to the rose of dawn, and the German professor detects 'the Keltic *ros*, a promontory,' is a simple translation of the Gletscher Mons of Simler, or rather Simler's hybrid term is a translation of Monte della Roesa. Roesa, or Ruize, is the Val d'Aostan word for glacier, and may be found in De Saussure's 'Voyages.'

An important case in this matter of mountain nomenclature has recently come under discussion—that of the highest mountain in the world. Most, if not all, mountaineers regret that the name of a Surveyor-General, however eminent, was

fifty years ago affixed to Mount Everest. The ground for this action on the part of the Survey was the lack of any native name. Some years ago I ventured to suggest that the 29,002-feet peak (No. XV. of the Survey) was probably visible from the neighbourhood of Katmandu, even though the identifications of it by Schlagintweit and others might be incorrect, and that since some at least of the summits of the snowy group east of that city are apparently known in Nepal as Gaurisankar, that name might, following the practice which gave its name to Monte Rosa in the Alps, legitimately be applied to the loftiest crest of the mountain group of which the Nepalese Gaurisankar formed a part.

Recently, by the kindness of Lord Curzon, acting on a suggestion of my own, Captain Wood, a Survey officer, has been deputed to visit Katmandu and ascertain the facts. He has found that, contrary to the opinion of the late General Walker and the assertion of Major Waddell, Peak XV. is visible from the hills round the capital, and that the two highest snowpeaks visible from the city itself in the same direction were known to the Nepalese 'nobles' as Gaurisankar.

These latter peaks or peak are about 36 miles distant from Peak XV., but are connected with it by a continuous line of glaciers. According to the principles that have prevailed in the division of the Alps, they would undoubtedly be considered as part of the same group, and the name which, according to Captain Wood, is applied to a portion of the group might legitimately be adopted for its loftiest peak.

But the chiefs of the Indian Survey take, as they are entitled to, a different view. They have decided to confine the name Gaurisankar to one of the peaks seen from Katmandu itself. I do not desire to raise any further protest against this decision. For since, in 1886, I first raised the question its interest has become mainly academical. A local Tibetan name for Peak XV., Chomo-Kankar, the Lord of Snows, has been provided on excellent native authority, confirmed by that competent Tibetan scholar, Major Waddell, and I trust this name may in the future be used for the highest mountain in the world.[1] The point at issue is mainly one of taste. Indian surveyors may see no incongruity in naming after one of their own late chiefs the highest mountain in the world. But in this view they are, I believe, in a small minority.

I would urge mountain explorers to attempt in more distant lands what the late Messrs. Adams-Reilly and Nichols, Mr. Tuckett, and Lieut. Payer (of Arctic fame) did forty years ago with so much success in the Alps, what the Swiss Alpine Club have done lately, take a district, and working from the trigonometrically fixed points of a survey, where one exists, fill it in by planetabling with the help of the instruments for photographic and telephotographic surveying, in the use of which Mr. Reeves, the map curator to the R.G.S., is happy to give instruction. An excellent piece of work of this kind has been done by Mr. Stein in Central Asia.

There are, I know, some old-fashioned persons in this country who dispute the use of photography in mountain work. It can only be because they have never given it a full and fair trial with proper instruments.

Lastly, I come to a matter on which we may hope before long to have the advantage of medical opinion, based for the first time on a large number of cases. I refer to the effects of high altitudes on the human frame and the extent of the normal diminution in force as men ascend. The advance to Lhasa ought to do much to throw light on this interesting subject. I trust the Indian Government has taken care that the subject shall be carefully investigated by experts. The experience of most mountaineers (including my own) in the last few years has tended to modify our previous belief that bodily weakness increases more or less regularly with increasing altitude. Mr. White, the Resident in Sikhim, and my party both found on the borders of Tibet that the feelings of fatigue and dis-

[1] See, for discussions of this question, *Proceedings of the Royal Geographical Society*, N.S., 1885, **7**, 753; 1886, **8**, 88, 176, 257; *Geographical Journal*, 1903, **21**, 294; 1904, **23**, 89; *Alpine Journal*, 1886, **12**, 448; 1902–3, **21**, 53, 317; *Petermann's Mitteilungen*, 1888, **34**, 338; 1890, **36**, 251; 1901, **47**, 40; 1902, **48**, 14.

comfort that manifested themselves at about 14,000 to 16,000 feet tended to diminish as we climbed to 20,000 or 21,000 feet. I shall always regret that when I was travelling in 1899 on the shoulders of Kangchenjunga the exceptional snow-fall altogether prevented me from testing the point at which any of our ascents were stopped by discomforts due to the atmosphere. Owing to the nature of the footing, soft snow lying on hard, it was more difficult to walk uphill than on a shingly beach; and it was impossible for us to discriminate between the causes of exhaustion.

Here I must bring this, I fear, desultory Address to an end. I might easily have made it more purely geographical, if it is geography to furnish a mass of statistics that are better and more intelligibly given by a map. I might have dwelt on my own explorations in greater detail, or have summarised those of my friends of the Alpine Club. But I have done all this elsewhere in books or reviews, and I was unwilling to inflict it for a second time on any of my hearers who may have done me the honour to read what I have written. Looking back, I find I have been able to communicate very little of value, yet I trust I may have suggested to some of my audience what opportunities mountains offer for scientific observations to mountaineers better qualified in science than the present speaker, and how far we scouts or pioneers are from having exhausted even our Alpine playground as a field for intelligent and systematic research.

And even if the value to others of his travels may be doubtful, the Alpine explorer is sure of his reward. What has been said of books is true also of mountains—they are the best of friends. Poets and geologists may proclaim—

> 'The hills are shadows, and they flow
> From form to form, and nothing stands!'

But for us creatures of a day the great mountains stand fast, the Jungfrau and Mont Blanc do not change. Through all the vicissitudes of life we find them sure and sympathetic companions. Let me conclude with two lines which I found engraved on a tomb in Santa Croce at Florence:

> 'Huc properate, viri, salebrosum scandite montem,
> Pulchra laboris erunt præmia, palma, quies.'

The following Papers were read:—

1. *Cyrene: an Illustration of the Bearing of Geography on History.* *By* D. G. Hogarth, *M.A.*

This paper arose out of a brief visit paid to the Cyrenaica in April 1904 by a party, of which the author was one, conveyed by Mr. Allison Armour's yacht 'Utowana' to Derna, Ras Hilal, Marsa Susa (Apollonia), and Cyrene itself. Though barely a week in the country, the party was able to note certain geographical facts, which seem to explain the peculiarities of Cyrenaic history, and to illustrate the bearing of geography on history in general. The individual character of the Cyrenaica in ancient and modern times needs explanation, and the author called attention to the fact that the district is to all intents and purposes an island, without an island's usual ease of access. He described, first, the character of the coast on three sides of it, and then of the low-lying desert on the fourth side. In illustration of the coastal difficulties he narrated the experiences of the yacht last April at Marsa Susa and Ras Hilal. The existing society of the region derives its character from its isolation. The settled elements are few and recent, consisting of (1) Senusi immigrants, who selected the Cyrenaica as the home of the Order about 1850 on account of its inaccessibility; (2) Cretan Moslem refugees planted at various points in the past two years by the Ottoman Government. These have yet to prove that they can maintain themselves against the large unsettled Arab element, which emerges from and retires into the southern waste like pirates at sea. The author showed how the action

of the Senusis in regard to the Cyrenaica exemplifies a policy which has been misinterpreted.

He then inquired how far the modern geographical conditions represent the ancient, and said something on possible alterations in coast level and the nature of the ports, on which there is much to observe. Finally, he applied the known conditions to the ancient records and showed how far they accord with and account for them, and how far they are likely to influence also the future of the country. The ancient splendour and the modern fertility and amenity of the region were illustrated by photographic views, which also served to show something of the coastal difficulties.

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2. *Ptolemy's Map of Asia Minor: Method of Construction.* *By the* Rev. H. S. Cronin, *B.D.*

The way in which Ptolemy constructed his map of Asia Minor would appear to be as follows:—

1. He fixed, partly by the help of observations, partly by calculation of distances, the position of certain places to form, as it were, the four corners of his map. These were the four places he mentions by name in the first book of his Geography—Rhodes and Issus in the south, Byzantium and Trapezus in the north. The fixing of these positions really belonged to the construction of the map of the world, and was strictly prior to the construction of the special map. The area of Asia Minor, thus obtained, is very much too great; speaking roughly, it is a hundred miles too wide, and nearly as much too long. Herein lies the explanation both of his methods and of most of his mistakes.

2. In the next place he fixed the position of certain towns on the sea coast. This would be the natural order to pursue; and his adoption of this order is made probable by what he says himself in book i., c. 18, of the relative ease of dealing with maritime cities. Of inland towns he complains that it is impossible to ascertain their position relatively to each other or to the towns on the coast. The towns so fixed would include Perga on the south and Ephesus on the west.

3. He then proceeded to fix the position of certain towns in the interior, selecting for this purpose towns which stood at the junctions of important roads. Laodicea ad Lycum and Dorylæum would be of their number.

4. His method of fixing the position of these junctions can be demonstrated as follows:—

The distance of Laodicea from Ephesus and from Perga, measured on Ptolemy's map, agrees (or practically agrees) with the distance of Laodicea from Ephesus and from Perga, measured by road. A similar correspondence between map-distance and road-distance repeats itself too often in other cases to be the result of accident. The inference is that to fix the site, say, of Laodicea, he ascertained its distance by road from Ephesus and Perga; compasses and a little judgment would do the rest. The distance employed was the full distance by road; allowance for windings, if it were known, would have produced a desert in the interior of a map the area of which was much too big.

5. The distances from Ephesus (and Idyma) to Dorylæum and Amorium (measured in the two ways described above) do not correspond. It is otherwise with the distances from Byzantium to these two places measured by Nicomedia and Nicæa. Byzantium, therefore (or Chalcedon), was the point of measurement for the north-west.

6. The map-distances from Chalcedon to Pessinus and (apparently) to Ancyra also correspond respectively with the road-distances, if the latter be measured *viâ* Amorium in the first case and *viâ* Amorium and Pessinus in the second. The road distance to Tavium is some thirty miles too great. The positions, then, of Tavium and of other places east of the centre of Asia Minor were fixed from the east by measurements going back ultimately to Issus or Trapezus. This, again, is what we should expect.

7. It is worth while to notice that, although compression occurs where the two systems meet and the distance assigned to Ancyra from Tavium is not two-thirds of what it ought to be, Tavium is approximately the 'right' distance from Medæum, and the road from Tavium to Ancyra is represented with exaggerated windings on the map. A similar phenomenon is to be noticed on the road between Cyzicus and Nicæa, and is due again to local compression. The whole western coast line has been pulled in towards the east in order to suit the excessive distance between north and south.

8. Positions once fixed as suggested above would be used similarly to fix other road-centres. The details of the map would then be filled in as consistently as possible with the information available and the results already obtained.

9. Amorium is placed east and north of its correct position. As Ptolemy was working out his map—or, perhaps, as he was using the map of one of his predecessors—he would notice that Amorium lay not very far from the direct line from Dorylæum to Ancyra; he knew that a road led from Dorylæum to Amorium, and another from Amorium to Ancyra; to treat this route as the direct route was tempting, and on the whole least inconsistent with the facts as he conceived them. We may here notice the following figures and facts: Tavium to Cæsarea Mazaka, correct distance about 120 miles; distance on Ptolemy's map, 178 miles; distance by the road given in the Peutinger table, 191 Roman miles. The position of Tavium would be fixed from the north and east, of Mazaka from the east and south, with the result that on the map the *détour* would appear direct. Several of the towns on the road given in the Peutinger table are scattered about the line joining Mazaka and Tavium. Failing, then, a direct road which squared with previous results, Ptolemy sought and found an indirect road which was more amenable.

It follows from what has been already said that wrong conclusions are certain to arise from treating Ptolemy's map as if it were a modern map, or his geography as if it were a modern geography. An examination of his method of dealing with his facts may help us to recover those facts, which in their turn may afford clues to sites, to the course and length of roads, or may explain the aberrations of other authorities.

FRIDAY, AUGUST 19.

The following Papers were read:—

1. *The Fulani Emirates of Northern Nigeria.* *By* Major J. A. BURDON, *M.A.*, *F.R.G.S.*

The paper dealt especially with a portion only of Nigeria, and its descriptions are inapplicable to the territory as a whole. There is a wide distinction between the open bush of Northern and the dense forest of Southern Nigeria, a gradual change from the Sahara southwards being observable both in the vegetation and in Man. The latter has degenerated towards the south, but the English picture of the West African 'nigger' is inapplicable to the higher type of the north. The southward progress of Islam has been checked by the forest belt, and paganism holds its own in the south. No community is possible between the two systems, and recent disturbances in pagan districts are in no way connected with northern feeling. For a general description of Nigeria reference may be made to papers by Sir Frederick and Lady Lugard, the present description being restricted to the western districts known to the writer personally. The greater part of these are occupied by a Laterite plateau (broken about the tenth parallel by a granite belt) characterised by great monotony. Through it the Niger and its affluents have cut themselves broad flat valleys, and as a result of the action of the numerous rivers the surface has been broken into a succession of table-topped hills. Generally speaking, the rivers—broad expanses of dark rushing water in the rains—become in the dry season blistering sand tracts, soon overgrown with dense scrub,

To the south, however, they flow through belts of dense forest. The nomad inhabitants—the Fulani—rose to power under the leadership of Othman Dan Fodio a century ago. The war which then ensued was racial, not religious, in its origin, but developed into a Jihad in which religious leaders were raised to power. Apart from the ruling caste the Fulani type has remained unchanged, a striking contrast being observable between ruler and herdsman, alike in fighting qualities, in purity of race, in education, and in intelligence. Qualities of justice and patience are greatly developed in the ruler, whose character appears to have been formed in part by admixture with the Negro type.

There were varying degrees of resistance to the Fulani conquest, and its effects in the non-Mohammedan south were very different from those in the north. The sweeping accusations of oppression, based on facts observed in the south, are not always deserved.

Underlying all the State systems is a deeply rooted constitutional idea, the Government depending on the will of the people. The tyranny of the late Emir Abd Errahman, of Sokoto, was an exception to the general rule. A typical example of the Fulani constitution is that at Bida. The fundamental principle is veneration for age, promotion being by seniority plus selection. The three estates of the realm are the Emir; the Council of Princes, through which the future Emir climbs the ladder of promotion; and the Council of Commoners. The two latter form a General Council for the consideration of important matters, the ordinary routine of State being carried on by a Privy Council. The evolution of this constitution is probably indigenous. There is a darker side of Fulani rule, but it is important to recognise and develop the best side.

The attitude of the British administration is one of construction, not destruction. In the impossibility of direct rule, what is needed is the education of the native rulers and adoption of the existing system. To speak of the 'downfall of Fulani rule' is therefore inaccurate. The feeling towards us is one of individual gratitude, tempered at present, however, by underlying resentment. The tolerance of the Kadiriyah sect, now in power, and the exclusion of the Senussiyah, give an augury of hope for the future.

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2. *Methods of Topographical Survey. By* Major C. F. Close, *C.M.G., R.E.*

1. The days of geographical exploration are drawing to a close. The greater part of Africa is, for instance, no longer a field for the explorer. Geographical societies will be obliged to devote an increasing amount of attention to topographical surveying.

2. Whatever the methods of a topographical survey, they should be judged by the resulting map; and in forming a judgment the three chief considerations are accuracy, legibility, cost. We may further subdivide the first heading into accuracy of detail and contouring, and the second into interval of contours, clearness and number of colours, hill shading, lettering, bearing of edges, scale, conventional signs. If we examine some of the principal topographical maps on these lines we shall be able to divide them into groups. Thus, *first-class* topographical maps will include the Ordnance coloured 1-inch, the French Colonial $\frac{1}{50000}$, and the American topographical maps of the Geological Survey. *Second-class*, the German $\frac{1}{25000}$, the Spanish $\frac{1}{50000}$, and so on.

3. It is perhaps possible that a class of topographical maps might be devised which should show the main features at a glance and the minor features by means of a magnifying glass. Simple reduction will not effect this. Such a type of map would be of the greatest value for all the ordinary purposes for which a map is used.

4. As regards cost, it is important that money should not be saved at the expense of the clearness of reproduction. The reproduction should do full justice to the field sheet.

5. *Topographical Methods.*—The *horizontal structure* of a map must first be considered. This consists of a framework of the first order, a framework of the

second order, and a framework of the third order; and so on. A perfect map is, in fact, formed of points of six orders of accuracy, and it is approximately true that the accuracy of direction of any line joining adjacent points of the same order will vary directly as the length. The control of the 'relief,' the vertical framework, is similar; here we have points of five orders of accuracy, from the primary levelling to the freehand lines joining the contour points.

6. In forming this structure only one alteration of principle has of recent years been attempted—namely, the use of photography for topographical purposes. It is, however, a method which has a very limited field of usefulness. It has been successfully used in Canada in very special circumstances, but ordinarily the topographer working on customary lines will be quite prepared to prove the superiority of the recognised methods in the matters of accuracy, rapidity, and cost. An extension of an old principle, recently employed with effect on the Gold Coast, is described below.

7. The following is a brief description of the methods (in use or proposed) of forming topographical maps in the British Empire:—

(1) *The United Kingdom.*—The small-scale maps of the United Kingdom are formed by reduction from the 6-inch map, which itself, so far as detail is concerned, is reduced from the $\frac{1}{2500}$. The resulting map is of the highest possible accuracy. Of course this system cannot be employed as a general rule on account of the expense, and would not have been used at home were it not that large-scale maps (cadastral maps) are a necessity.

(2) *India.*—Vast areas in India have been topographically surveyed by triangulation and plane-tabling. It is especially interesting to study this system at work during an expedition. The recent operations in China afford a noteworthy example; the Survey of India party surveyed about 17,000 square miles on the $\frac{1}{2}$-inch scale. Similar work is now going on in Tibet.

(3) *The Gold Coast.*—In the survey of this territory we find, for the first time, 'long traverses.' The expense of triangulation in such dense forest would be prohibitive. Hence the country is being divided up by long primary traverses, and at the junction-points of these traverses latitudes are observed having an apparent probable error of 0·2″. It is easy to show that on account of 'local attraction' it is no use multiplying the number of these latitudes. The average length of a traverse is about 70 miles.[1] Between these traverses minor and compass traverses are run. Here we have points of the second and lower orders.

(4) *South Africa.*—Whenever the systematic survey of South Africa is commenced it will start under most favourable conditions. First because, thanks to Sir David Gill and Colonel Morris, the geodetic triangulation of the Cape Colony and Natal is complete, and that of the other colonies is progressing. Secondly, the country is for the most part very suitable for a plane-table survey. The accuracy and economy of plane-tabling are at their greatest in an open country provided with scattered hills, and much of South Africa answers to this description.

(5) *Canada.*—At the request of the Dominion Government, Major Hills, the head of the Topographical Section of the War Office, drew up a report, after consultation in Canada, which forms a valuable scheme for the topographical survey of this vast territory, a scheme which it is much to be hoped will be carried out. It comprises, in brief:—

i. A geodetic arc from the St. Lawrence to Vancouver.
ii. Secondary chains depending on this.
ii. A topographical triangulation covering the interstices with a network.
v. Topography (to be carried out mainly by plane-tabling); the standard scale to be $\frac{1}{2}$ inch to 1 mile.

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[1] Two traverses were lately carried out independently between points 140 miles apart, the results showing a difference of 25 feet only at the terminal point.

3. *The Glaciers of the Caucasus.* *By* Maurice de Déchy.

The author commenced his paper with a sketch of the manner in which the ideas prevalent in Europe with regard to the small dimensions of Caucasian glaciers were first created by incomplete maps, and subsequently dissipated *ambulando* by the incursions of English and other climbers into the mountain recesses. He proceeded to give statistics as to the snow-level in different portions of the Caucasus (showing that it rises towards the Caspian), and a detailed enumeration of the length and dimensions of the principal glaciers of the chain, and the depth to which they descend below the snow-level in various localities. He then dealt with the oscillations of the ice, which appear to have corresponded during the last fifty years with those of the Alpine glaciers, and concluded by a reference to the evidences that remain of the large extension of prehistoric glaciers on the flanks of the mountains.

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4. *Scenes and Studies in the Nile Valley.* *By* Arthur Silva White.

Especial stress was laid on the organic unity of the Nile Valley as a physical fact of great political significance. The river and its tributaries flow from the heart of Africa to the far-distant Mediterranean littoral, being surrounded on all sides save one by desert and steppe lands. The watershed passes over barren and uninhabited tracts, except in the extreme south-west, where it abuts on the Congo basin. The Nile Valley may therefore be said to be physically isolated.

Politically, no less than physically, Egypt turns her back on Africa and faces Europe and Asia, with the fortunes of which continents her past development has been closely associated.

These considerations point to the recognition of the complete unity of the Nile basin as the basis of a national policy imposed by Nature and dictated by the teaching of history. Egypt, from the time of Alexander the Great to the present day, has always been dominated or controlled by the Power holding the command of the sea. Her physical and political insularity is, therefore, a fact which sufficiently accounts for the present situation.

MONDAY, AUGUST 22.

The following Papers and Report were read:—

1. *A Journey around Lake Titicaca.* *By* Arthur W. Hill, *M.A.*

Lake Titicaca is situated at an elevation of 12,500 feet above sea-level between the eastern and western ridges of the Cordillera of the Andes.

The journey was made during the spring of 1903, which is the rainy season on the plateau. From La Paz, the capital of Bolivia, the route lay along the southern shore of the lake to Tiahuanaco, where there exist some of the finest and most ancient stone monuments in South America; thence to the Desaguadero, the only stream flowing out of the lake, and across this, going eastward to Copacabana. Here some stay was made, and the sacred island of Titicaca, with its Inca temples and palaces, was visited.

The ancient terracing of the hillsides for cultivation is very marked in this region, and the terraces are still in use. The crops usually grown are barley, potatoes, quinoa (*Chenopodium*), ocas (*Oxalis*) and beans; wheat and maize can only be grown in sheltered spots at this elevation.

On returning to Copacabana an interesting Indian festival was found to be in progress, which, though avowedly Christian, showed strong resemblances to some early pagan ceremony. The narrow straits of Tiquina were then crossed and the

journey continued along the north-eastern shore of the lake, with digressions into the eastern mountains, and plants were collected up to about 16,500 feet. The majority of the plants show a striking uniformity as regards their vegetative habit, and grow usually in rosettes or mounds; they have long tap roots, which enable them to absorb water from the warmer soil at a considerable distance below the surface, and their leaves are usually linear and often hairy. These peculiarities are induced by the climatic conditions, since the plants have to endure a burning sun during the day, followed by frost, with cold, cutting winds, at night; there is often a difference in temperature of as much as 70° F. in a few hours. The journey was continued round the northern end of the lake, where the Indian huts are built of mud bricks in the shape of beehives, and was terminated at the Peruvian port of Puno, whence runs the railway to Arequipa and Mollendo.

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2. *Glacier-bursts. By* CHARLES RABOT.

Glaciers give rise to torrential phenomena known by the name of 'débâcles,' or glacier-bursts, the geological importance of which has hitherto been insufficiently recognised.

The production of an outburst depends on the prior creation of a reservoir of water and its sudden discharge. The creation of this reservoir may be the result of an advance or retreat of the glacier, which has the effect of stopping the outflow of the waters into a *thalweg*; it may equally be the consequence of the present state of the glaciation, which may permanently block the valley. Lastly, the body of water necessary to the production of an outburst may be formed either above or below the glacier, or even within its thickness. When the barrier of ice yields the outburst takes place, and its violence is proportional to the cubic contents of the reservoir and the slope of the ground over which the inundation passes. In the Alps twenty-five glaciers have been the scene of outbursts, either singly or in series, whose causes are matter of knowledge, but many others have produced inundations whose mode of origin has escaped observation. The total number is certainly much greater, but only the most destructive had been recorded prior to 1892, the date of the Saint Gervais catastrophe.

These torrential phenomena occur in all the glaciated mountain regions of the world—in Norway, Iceland, Spitzbergen (where Sir Martin Conway and Professor E. J. Garwood have noted their effects), in Greenland, Alaska, and, lastly, in the Himalayas. In the last-named region English travellers, like Col. Godwin-Austen, Sir Martin Conway, and Professor Norman Collie, have collected valuable data bearing on this phenomenon. In the Alps, the volume of water precipitated in the case of destructive outbursts may reach several million cubic mètres, and this enormous liquid mass may flow away in a few hours over steeply sloping ground. In 1878 the Marjelensee discharged 7,700,000 cubic mètres in nine hours, and the Gietroz outburst in 1818 attained a volume of 530 million cubic feet.

Such a mass of water moving at an enormous speed has an important erosive effect, and modifies the contours of the valley along which it takes its course. On the other hand, it carries with it enormous masses of material, and, frequently, large numbers of trees. All these *débris* are afterwards deposited in the locality where a diminution of the angle of slope brings about a reduction in the rate of flow. Thus, in valleys visited by frequent catastrophes, we may say that the glacial deposits of the present day or of Pleistocene age have been, and are still being, shifted and rearranged throughout the whole of the zone affected by these wild waters. Similar inundations must necessarily have been very frequent during the glacial epoch, and frequent mistakes must have been made in studying the Pleistocene formations through not taking account of these phenomena. Still, we must not go too far and exaggerate the action of glacier-outbursts. Their effects are at the present day limited to the sides of the *thalwegs*, and the same must have been the case during the Quaternary period.

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3. *Report on Terrestrial Surface Waves.*—See Reports, p. 301.

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4. *Brunanburh: Identification of this Battle Site in North Lincolnshire. By the* Rev. ALFRED HUNT, *M.A.*

No modern historian of repute is able to name the site of this famous battle of the tenth century—fought between the Saxon king Athelstan on the one hand and Anlaff the Dane and Constantine, King of Scotland, on the other—though most are agreed as to the importance and greatness of the battle. The numbers engaged are supposed to have been over 120,000, and the result of the battle was to raise England in the councils of Europe to a position never reached before. The present paper suggested reasons for the belief that this battlefield is to be found in North Lincolnshire, at the hamlet of Burnham, in the parish of Thornton Curtis, within four miles of the Humber.

Geographical considerations send us at once to the river Humber and district in search of the lost site, while many of the old writers agree in saying that Anlaff entered the mouth of the Humber, and that the battle was fought near by, though silent as to where Anlaff landed and encamped. Now, as is evident from the form of the river Humber, this landing must be placed between Spurn Head and the junction of the Ouse and the Trent, either on the Lincolnshire or Yorkshire side; and it is probable, from the statements regarding the number of Anlaff's vessels (615) and troops, that he divided his forces, sending a portion against the Saxon outpost at Brough (the Roman Petuaria), on the Yorkshire side, and also effecting a landing at Barrow Haven, a tidal and navigable stream on the Lincolnshire coast.

At Barrow Haven there are extensive earthworks of the usual Danish form of construction for an entrenched position, covering an area of eight acres, and locally called Barrow Castles. It was suggested that these were thrown up by Anlaff on landing. South of Barrow Castles, and four miles away, is the hamlet of Burnham, believed by the writer to be the true site of the Battle of Brunanburh.

At Burnham extensive lines of entrenchments, covering over sixty-four acres, of a totally different character from those at Barrow, are still to be seen, while local tradition has always said this was a great battlefield. There is a perennial stream at the rear of the camp which was the only surface-spring known for seven miles across the Lincolnshire Wolds. In Domesday Survey this hamlet is entered as Brune in the parish of Thornton Curtis, while in the 'Welsh Chronicle of the Princes' and in the 'Annales Cambriæ' the battle is called the Battle at Brune. Adding to this name the possessive termination, *an*, together with the Anglo-Saxon 'burh' (camp or earthwork), we at once have the long-lost word Brun-an-burh.

From this camp, burh, or earthwork the two main Saxon roads from the West and South of England called Ermine Street and Fosse Way are available for Athelstan's support. At Castlethorpe a few miles south-west and near the present town of Glamford Brigg, which commands the only place of crossing the river Ancholme, are extensive earthworks of a similar nature to those at Burnham. Here was discovered in 1884 a Danish raft constructed like the famous Gokstad boat or Viking ship.

The best geographical description of the land and place of battle is given in Egil's Saga. This tells us that Athelstan came northwards to repel the invasion by the Humber; that the battle took place by Vin-heath, or Vin-wood; and that the land sloped towards the north. North of the heath stood a town occupied by Anlaff and Constantine. South of the heath was another town to which Athelstan came, and to which he returned after the battle.

All these conditions are fulfilled in the case of Burnham. The town in the north is Barrow, that in the south Glamford Brigg; the ground slopes north from Burnham; there is still one field of Vin or Whin left; while the whole of

the South and West of England would be open for the arrival of Athelstan's supporters.

The battle was a final struggle for supremacy between the North and the South, resulting in favour of the South.

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5. *The Lipari Islands and their Volcanoes.* *By* TEMPEST ANDERSON, *M.D.*, *B.Sc.*

TUESDAY, AUGUST 23.

The following Papers were read:—

1. *Exhibit of Maps and Photographs showing Effects of Earth Movements near Naples; with a Note on the Area affected by them.* *By* R. T. GÜNTHER, *M.A.*

The Committee appointed in 1900 for the investigation of coast changes in the Bay of Naples laid a brief Report before the meeting of 1901, but the complete results[1] were not published until after the meeting last year. The exhibit now made consists of maps and photographs showing some of the results of the work. The land-levels illustrated are three in number:—

1. The Græco-Roman land-level (about 16 feet above the present).

The large map exhibited is an original survey of the present coast-line of Posilipo, upon which the submerged foundations of buildings and a conjectural restoration of the ancient Roman foreshore are marked. The submerged artificial remains discovered were grouped in three regions, of which the largest, the Gaiola region, seems to have been dry for about a quarter of a mile beyond the present shore. Here were seen the foundations of those colonnades, temples, and pavilions by the sea, moles and harbour works, of which so many frescoed drawings still exist. Between the submerged regions, Naples, and Pozzuoli are indications of an ancient roadway, which probably became impassable when the land subsided. Corroborative evidence of this Græco-Roman land-level was obtained at Misenum, Capri, Sorrento, and elsewhere in the Bay of Naples.

2. The Medieval Land-level (12–23 feet below the present, and thus in places about 40 feet below the Græco-Roman land-level).

Photographs showing erosion lines etched at this period at Capri, Sorrento, Pozzuoli, Nisida, &c., are exhibited.

3. The Modern Land-level.

Recently the author has endeavoured to extend his work by tracing the influence of the changes of land-level upon the growth of the city of Naples,[2] and more especially upon the positions of its harbours and buildings on the foreshore. The real site of the Roman harbour of Neapolis was not, he considers, situated where archæologists would have it—viz., some way inland, where ruins of a so-called Roman lighthouse are stated to have been found near the churches of the Gesù Vecchio and S. Giovanni Maggiore, but further south at a lower level. The classical foreshore sank during the Dark Ages till by the eleventh century the sea reached far inland, in fact as far as the rising ground upon which the southern ramparts of the town were built. The land was at this low level when the great Angevin constructions, the Castel Nuovo, the Molo Piccolo, and the Molo Angivino, were commenced. The subsequent upward movements were of an irregular and discontinuous character, and the land has not returned to the Roman level by some 16 feet.

There are reasons for believing that these changes have affected a wide area. The author has already shown that they have not been confined to the Bay of Naples, but extended as far north as Rome and as far south as Pæstum. There

[1] *Geographical Journal*, August and September, 1903; *Archæologia*, vol. lviii.

[2] *Geographical Journal*, August, 1904.

is now evidence of their effects across the entire width of the Mediterranean from north to south. Not far from Genoa stands, close to the water's edge, the once celebrated monastery of S. Fruttuoso, said to have been founded in 409, when, in accordance with the theory outlined above, the present shore would have been higher above the sea than it now is. The building is supported on arches, through which were rowed, between 1275 and 1305, the mourning barges bringing here for burial the illustrious dead of the Dorias. At the present day the arches stand so high that the water does not even touch their piers. This is an indication that the coast of Northern Italy was relatively low during the thirteenth and fourteenth centuries, that is, at a period precisely corresponding in time with the period of the greatest submergence of the Neapolitan shore.

Again, it is held by competent authorities that during the classical period, and earlier, the Delta of the Nile was at a relatively much higher level above the sea than it is now—an idea fully borne out by Professor Petrie's excavations in Lower Egypt. We have, therefore, good reason for believing that a large area of the Mediterranean basin was affected by the same movement.

It is to be hoped that exact measurements of differences of land-levels will be made wherever possible. Many of the author's measurements near Naples show variations amounting to as much as 11 feet in 2 miles, and are thus evidences of considerable tilting of strata since the medieval period.

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2. *On the Nomenclature of the Physical Features of England and Wales.* *By* Hugh Robert Mill, *D.Sc.*

Although innumerable place-names strew the large-scale maps of England and Wales, these refer chiefly to the smaller features, and when an orographical map is drawn on a small scale it is difficult to find appropriate names for the larger features of the vertical relief of the country.

The names now suggested have been authorised by the Council of the Royal Geographical Society, on the basis of a scheme elaborated by a Committee of the Research Department of that Society, consisting of Mr. H. J. Mackinder, Mr. Chisholm, and the writer, and the map on which the work was done has been prepared by Mr. Bartholomew.

Amongst the larger features recognised are the Eastern Plain, extending from the Vale of York into Essex; the constituent members of the Oolitic Ridges, viz., the Cotteswold Hills, Edge Hill, the Northampton Uplands, the Lincoln Edge, and the North York Moors; the constituent features of the Chalk Ridge, viz., the Western Downs, Hampshire Downs, and the Weald on the south, and the White Horse Hills, Chiltern Hills, East Anglian Ridge, and Lincoln Wolds on the north. Special attention is bestowed on the naming of the gaps between the various groups of high land, and the whole constitutes a groundwork which it is hoped will be utilised in future maps. Where a large feature had no accepted name, one was provided by either of two processes—(*a*) somewhat widening the application of an existing name, as in the case of the Bowland and Rossendale Forests, the two almost detached pieces of high ground budding off from the Pennine Chain on the west, and (*b*) by introducing a new name so devised as to be in close harmony with existing names, such as the Western Downs, Forest Ridges, Lincoln Edge.

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3. *Changes in the Fen District.* *By* H. Yule Oldham, *M.A.*

This paper dealt principally with changes in the river system of the Fen District since the seventeenth century, brought about by the cutting of the two great drainage channels across the Bedford Level and the building of the sluices across the old course of the Ouse at Denver. It was illustrated by representations of old maps of the district and by lantern-views.

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4. *Vegetation of the Fen District.* *By* Professor R. H. YAPP, *M.A.*

This paper, which was illustrated by lantern-views of the characteristic vegetation of the Fen District, described in turn the principal plant associations represented, pointing out the importance of the aquatic or semi-aquatic forms, and briefly describing the life-conditions of each.

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5. *Notes on the Malabar Coast of India.* *By* R. S. LEPPER, *M.A., LL.M.*

The country dealt with extends along the West Coast of India from about 16° to 8° N., and inland to the watershed of the Western Ghats, a breadth of from thirty to sixty miles. The coast is so exposed that marine navigation is practically suspended during the early months of the S.W. monsoon, but a remarkable system of rivers, lagoons, and canals, stretching throughout Travancore, Cochin, and the Malabar district for about 200 miles, facilitates communication. There are practically no harbours except in the north, the old ports having long ago been closed by the silting up of their rivers and the formation of bars by the surf. The governing features are the Western Ghats and the S.W. monsoon, which precipitates a deluge of rain during the summer months. These mountains rise precipitously from the hilly and thickly wooded country below, and are covered with primeval forest of great value. The climate is very moist, and the range of temperature very slight. Rivers are many, but short and shallow, navigable only in dug-out canoes and at certain seasons of the year. Towards the sea they expand into broad lakes or winding lagoons, caused in the south by the formation of sand-dunes. Towards the north, where the mountains are closer to the sea, there are often fine waterfalls, including the stupendous Gersoppa Falls, near Honawar, with a sheer drop of 800 feet.

The mineral wealth has been but slightly exploited, but the vegetable products are of the greatest importance. The mountains grow tea, cinchona, coffee, and cardamoms; the forest slopes fibres, pepper, nutmegs, cloves, &c.; the plains tapioca, palms of all sorts, plantains, and rice. Rubber is being introduced with good hopes of success. The forests provide an immense amount of valuable timber, such as teak, blackwood, ebony, sandal, and bamboo. They abound in big game: elephant, tiger, bison, deer, &c. The red laterite soil, rich vegetation, and green rice fields, mountain and river views, make the scenery wonderfully beautiful.

Ethnologically the country is very interesting but very puzzling. The population is essentially Dravidian, but has been considerably modified by Aryan (Brahman) settlers, through the prevalence of the matriarchal family system. In the mountain and forest parts many odd and isolated racial fragments are found, belonging to all stages of civilisation, and suggesting that here is to be found the ethnical substratum of South Asia. Dress, arrangement of hair, architecture, and family system are all quite distinct from those of the East. Religious systems vary, from tree, snake, and devil worship, and other primitive faiths, up through Saivite Hinduism to philosophic theism. Caste still exercises a potent influence. The modern use of the term obscures the fundamental identity of race and caste, and the perfectly natural origin of ceremonial pollution, through the connection between godliness and cleanliness. At first a necessary good, caste is now, perhaps, a necessary evil. In Malabar it is much complicated through the matriarchate.

The early history of this coast is very obscure. In modern times the chief events have been the founding of the State of Travancore by King Marthanda Varma, the rule of Hyder and Tippu in Mysore, and the overthrow of the latter by the British, followed by gradual pacification and progress. Serfdom still lingers, though no longer enforceable by law.

The chief towns are along the coast, usually near the mouths of rivers, which are the chief means of communication. The Malayali style of architecture, with concave roof-ridges and carved wooden gables, is quite distinct from any other style in India, and is probably due to the use of bamboo and teak for building.

Population is very irregularly distributed and its increase but slight. As in the tropics generally, it has a much smaller administrative value than population in a temperate climate. Even in India this value varies greatly. The contrast between the East Coast and the West Coast population of South India is very marked, the cause being in part racial, in part climatic. The commercial importance of the Malabar coast depends mainly on its raw products. Cocoanut fibre and oil, spices, tea, and coffee are exported; rice imported.

The Malayalis have hitherto somewhat lagged behind the Tamils of the East Coast, but are rapidly catching them up, though not yet so disciplined, methodical, persevering, or enterprising. Among their characteristics are good-nature, hospitality, politeness, piety, and personal cleanliness. The type represented by the Bengali Babu is not found in South India or Bombay. The real new Hindu is very different from 'Mr. Jabberjee,' and usually stays in India. Contempt for him is altogether inappropriate and often grossly unfair. The great need is for a sane and intelligent sympathy and for co-operation on a fair and stable basis.

In conclusion, the author pointed out the astonishing progress which has been made in the Malabar Coast States during the last fifty years, and insisted on the need of firm but tactful and sympathetic treatment of old institutions, of efficiency, honesty, and continuity in administration. South India could best be helped by giving her ablest sons the highest possible training and education.

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6. *A Geographical Object-lesson: Passes of the Alps.* *By* A. W. Andrews.

The grouping of the scattered information which constitutes geographical knowledge is essential for a true understanding of the influence of physical features on the life and intercourse of the inhabitants of any region.

Only those who can travel or have leisure and opportunity to read widely, to study photographs and maps, and to think out the relations of cause and effect, can hope to grasp the inner meaning of history and geography, and unfortunately the majority of teachers of geography do not, as a rule, belong to this small class.

It has therefore been suggested that a series of object-lessons should be put together in the form of lantern slides, each lesson dealing with one aspect of geography such as peaks, passes, and glaciers, coast lines, regions of vegetation, &c.

It is proposed also to prepare a short pamphlet on each subject, explaining the maps and views and containing suggestions as to their use. It is hoped that the first two sets, peaks and glaciers, and passes of the Alps, will be ready for use in September.

The paper gave a general sketch of the aims and constitution of a typical set, including geographical and political maps of the Alps and their main subdivisions, maps showing river basins, railways, &c., with views of characteristic natural features.

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7. *The Scottish Antarctic Expedition.* *By* W. S. Bruce.

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8. *The First True Maps.* *By* C. R. Beazley, *M.A.*

This paper dealt with the 'Portolani,' or coast-plans, intended as practical guides to sailors and merchants, which made their appearance at the close of the thirteenth and beginning of the fourteenth century, and which are not only the first true sea-charts, but likewise the earliest designs in which any part of the earth's surface is laid down from actual observation of a close and continuous character. In their almost modern accuracy they form a striking contrast with the results of the older literary or theological geography, and the problem of their sudden appearance in such comparative perfection is deserving of more study than it has yet received, at least in this country.

The author described the general characteristics of these Portolani, tracing their evolution from the 'Carte Pisane' and the first design of Giovanni de Carignano (of the opening years of the fourteenth century) to the more complete examples, in which certain characteristic representations of the coasts dealt with have become more or less established. In contrast with the uniformity of the general features of the maps, the loxodrome network displays great variation, two designs of exactly similar character in this respect being rarely met with. As regards the origin of the Portolani, he upheld the views of Fischer (as opposed to those of Nordenskiöld), that the chief credit in the matter justly rests with the Italians rather than the Catalans, and pointed out the difficulties in the way of accepting the Byzantine origin suggested in 1881 by Fiorini. He concluded by showing how all genuine progress in geographical delineation followed the lines of the Portolani, and pointing out that their failure for long to meet with just appreciation was due to the fact that they never attempted to gratify popular taste.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Professor William Smart, M.A., D.Phil., LL.D.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

For the last two years I have been continuously engaged, as a Commissioner, in studying the phenomena of the Housing of the Poor and the problems which arise therefrom, as presented in the evidence laid before the Glasgow Municipal Commission. It is, perhaps, appropriate that I should draw upon the experience thus gained for the substance of my Address to-day.

The problem of housing in Glasgow is, in broad outline, very much the problem of all large centres of population and industry. The city grew up, without a plan, in days when the laws of public health were little understood or cared for; when there was little municipal control and little thought for the municipal future. It has now to undo its mistakes.

Fifty years ago people had not, I think, a very keen sense of smell; certainly they did not associate bad smells with danger to health. They did not regard the darkness of the narrow street and the narrow window as objectionable. If I may trust my early recollections, as one who has lived in Glasgow from childhood, they associated smoke too much with their bread and butter to dream of grumbling at it. They were rather afraid of cold water, and baths were almost unknown. Perhaps they were fonder of each other's society than we are; at any rate, they rather preferred to live as many as possible in one room and sleep three in a bed.

When the city came to its senses, about forty years ago, and realised what an Augean stable there was to clear out, it turned to the work with a will. Considering the still unformed state of public opinion, the City Improvement Act of 1866 was a very drastic one. It scheduled whole areas of slums and pulled them down, dishousing, within five years, some 19,000 persons; rating for deficits to the amount of some 600,000*l.* altogether; and the burden was borne without much demur. By the time the Act had done its work, the public mind had become thoroughly awake to the danger of letting things alone. Further powers were asked and obtained for closing, demolition, and rebuilding. Four years ago was passed the Building Regulations Act, which, in addition to regulating the construction of new houses, made the provision of sufficient air and light space in front of the bedroom windows compulsory, and this was so far retrospective that over 4,000 houses, conforming to sanitary requirements in other respects, became on a certain date 'illegal houses' simply from the fact that they had not the sufficient space outside.

These measures did not pass without criticism, but generally it was recognised that they were demanded in the interests of public health. When, however, it was realised that dishousing on this large scale was accepted by a very large section of

the Municipality as logically calling for municipal housing on a similarly large scale, public attention was roused. It began to come home to the citizens that very gigantic operations were being carried out, and very gigantic responsibilities for the future being incurred, without, as it seemed, any thorough diagnosis or any definite plan. The whole problem was seen to be one which, in other circumstances, would have called for a Royal Commission. The demand was made for a local inquiry on similar lines; and, when the Prime Minister gave his cordial approval to such an inquiry, the Municipality appointed a mixed Commission of nine councillors and six private citizens, with a remit to examine (*a*) the causes which led to congested and insanitary areas and overcrowding; (*b*) the remedies which could or should be adopted for the clearance of existing congested, insanitary, and overcrowded areas, and for the prevention of these evils in future; and (*c*) any other phases of or questions connected with the housing problem in Glasgow which the Commission may deem it desirable, necessary, or expedient to consider and report upon.

The evidence, report, and recommendations are now before the public. Generally speaking, they bear out the conclusion that many things hitherto discussed as parts of the Housing Problem are not problems at all, but phenomena which merely need to be known to secure that they are put an end to. Slums must be cleared away; streets must be widened; overcrowding must be prevented; the liberty of the landlord to sell and of the tenant to use insanitary houses must be interfered with; light and air space must be guarded as a right of the poor. These are dictates of public health and public morals, and the Commission calls for the firm administration of powers which the Municipality already has and for further powers where these are not sufficient.

Connected incidentally with this there are, indeed, minor problems, such as questions of procedure, of acquisition, of compensation, and the like; but, so far as I am able to judge, the real Housing Problem of to-day narrows itself down to this: how far the experience gained points in the direction of the Municipality itself building and owning houses for certain of the poorer classes.

To this the Commission has contributed an answer in so far that, in the special circumstances of Glasgow, it recommends a limited scheme of municipal building and owning. But it adds the words 'without expressing any opinion upon the general policy of municipal housing.'

I venture to think that there is no more pressing duty now incumbent on economists than to take up this general question. I propose, then, first, to consider building and owning of house property as a branch of municipal activity; and, secondly, to examine the particular circumstances which suggest a revision or relaxation of general principles.

For a Municipality, deliberately and of set intention, to add a new competitive industry to its already manifold activities, is a serious matter from three points of view.

(1) House-owning is a business, and it is neither a routine business nor one where success is certain. So far as it has not a monopoly, a Municipality cannot presume upon demand—cannot command a remunerative sale for what it provides. As a builder, it has advantages and it has disadvantages; as an owner, it has also advantages and disadvantages—particularly, perhaps, in that it has a conscience.

Assuming, however, that a Municipality can manage its enterprises as well as private citizens manage theirs, and that its house-owning covers all recognised expenses and runs no risk of coming upon the rates, what must be emphasised is that it pledges the future ratepayers for the security of all the capital borrowed. It is short-sighted to conceal the dangers and responsibilities of this by calling such a debt 'productive.' Borrowed capital changed into stone and lime certainly remains an 'asset,' but whether the asset is worth much, or little, or nothing, depends on the value which future generations will put upon it. An old mill may be 'good' for half a century more as a building, and yet be worth less than nothing as a mill. So may a tenement of houses, by change of circumstances, lose

its rent-producing capacity and call only for demolition long before it has suffered much deterioration as a building. In such circumstances the ideal kind of house would be one constructed to last, say, thirty years at the outside. But this, of course, is the last thing that Municipalities in their present mood would think of doing, and they generally make it impossible by their own building regulations. Besides this, there is the consequence of the 'economic trespass;' that dwelling-houses for the poor generally take up the space of buildings of a more remunerative character, and so keep down the rateable value of the area, while increasing its expenses.

(2) It enters into direct competition with many of its own ratepayers, competing not only with the comparatively small class of builders, but with the great class of owners of house property. Apart from the equity of this, which is too large a question to enter on here, the results may be very serious. Free competition of producers to serve the public is, of course, a good thing, and in nothing, perhaps, is it more desirable than in the purveying of houses, where the length of time required for erection tends to some extent towards monopoly. But competition is good because, and to the extent that, it keeps down prices by increasing supply, and the action of a Municipality working with money borrowed at a gilt-edged security rate is very likely to have the opposite effect; it may result in a positive diminution of the total supply of houses, and so a rise of rent, by reason of the discouragement given to private builders through the appearance of a rival with whom they cannot compete on equal terms. The monopoly which Municipalities secure for their other industries prevents such a danger; but it must be emphasised that a Municipality supplying a few hundred houses, where the well-being of the citizens as a whole depends on private enterprise continuing to supply some hundreds of thousands, occupies an entirely different position from a Municipality providing *all* the water, gas, electricity, and tramway service which the citizens may demand.

(3) By pledging the public credit for a new debt, and adding a new activity and responsibility to already overworked members of the Municipality, it *pro tanto* prevents the expansion of municipal activity in other directions. Public functions, however admirable, must be limited by the public purse, and probably will be limited, long before that purse is exhausted, by the ratepayers' revolt against increased rates.

This must not be regarded as special pleading against furthur increase of municipal duties and expenses. Anyone who studies the growing complexity of city life and its increasing requirements of inspection, control, and administration generally, to say nothing of its possible expansion in other industrial and commercial directions, must be impressed with the necessity and magnitude of the tasks that lie before public bodies in the future, and must recognise the inexpediency of taking on any new burden without the most serious consideration. He will at least ask that the cost be counted and definite limits laid down. And these limits, in the present case, are not easily laid down. To mention only one thing: it would be exceedingly difficult, on grounds of equity, to justify the giving of an advantage to one class and refusing it to another, and, when that was done, to establish courts and criteria which should define and limit the class favoured. But unless such definitions and limitations were attempted, the Municipality would be embarked on an expenditure of which no one could see the end.

These are considerations against municipal building and owning derived from the general principles which should, in my opinion, regulate all municipal expansion. They are not, of course, decisive against it. But they suggest that very definite and weighty reasons must be put forward on the other side.

It will be admitted that the interests of public health, public morals, and industrial efficiency *are* definite and weighty reasons, and I should give the most sincere consideration to the argument of those who ask for municipal housing on such grounds. There are some respects in which the provision of houses seems to come under the natural work of a Municipality almost as much as do the provisions of gas and water. The house, as the condition of the home, stands at the

very centre of individual morality and health, and, as such, is a direct condition of the efficiency of labour. It is far too little realised that a sanitary and comfortable house among quiet neighbours has a 'productive value,' and is, quite definitely, one of the factors of wage-earning; in other words, a good house, as compared with a slum, brings with it the possibility of paying a higher rent for it. The point which specially suggests municipal building and owning is that municipal control over certain classes of house—control even violating the sanctity of the Englishman's castle—is necessary in these interests. We have in Glasgow 20,000 houses whose doors must open at any hour of the night at the knock of the sanitary inspectors. In a city every house is either a centre of good influence or of contamination material and moral, and, the more closely houses are packed, the more definite the need of positive control and regulation. Such control obviously would be most effective in the hands of a Municipality that owned the houses. In view, then, of the actual circumstances of slum life which prevail in every large city, and in view of the hopelessness of escape on the part of the low-paid wage-earner from such contagious influences, there seems *prima facie* a strong case for the provision of at least one- and two-roomed houses by an agency which would aim primarily at affording to the tenants the conditions of health, morality, and efficiency, not only in the construction of the houses, but in their continued administration and control. I have always held that the owning of poor-class property carries with it a moral responsibility which is not escaped by the owner shutting his eyes and leaving the administration to his factor; and, on similar grounds, much might be said for a Municipality owning and letting all the small houses within its area. This would at least secure a 'clean city.'

Such a position, then, is quite intelligible as a counsel of perfection, and it might be worth consideration in the case of a city planned, like a garden city, from the beginning. But, in the actual circumstances of our cities, I mention it merely to bring out my point. For there is no proposal before any Municipality of to-day of taking over and making a monopoly of the supply of small houses, or even of building all the small houses in the future. The utmost that has been proposed is the building and letting of a limited number of such houses in direct rivalry with private builders and owners. And the question which must be answered is: On what principle, or with what view, is this limited proposal made?

If it were to afford an experiment, and an object-lesson, as was done with the happiest results in the case of the Corporation lodging-houses in Glasgow, where the rise in the standard not only swept out the old and very objectionable lodging-houses, but led to the large increase of private 'models' competing successfully with the municipal ones, there would probably be nothing but approval. It seems a legitimate use of public money to make public experiments which would otherwise not be made, so long as it is recognised that experiments which fail should be given up. But if the proposal is made in the full recognition that such an experiment is not an object-lesson, inasmuch as it cannot be followed by private enterprise; if the reason given for it is that a certain class of tenants cannot pay the rent which private enterprise must have if it is to continue its supply, and that the Municipality, as having command of capital at a very low rate of interest, can afford to undersell the market rents without coming on the rates, the matter is put on an entirely different basis. The attractiveness of a 'clean city' is one thing; the attractiveness of low rents is another.

Let us look for a moment at the principles on which certain services are set aside for the Government to perform. The great mass of the national income is produced by individuals of the community dividing their labour and selling their products to each other, competing with each other as producers to serve the whole body of themselves as consumers. But there are two great classes of services which are not left to individual competition. (1) External defence, justice, police, poor relief, &c., are given over to the Government, the expenses being covered by taxation. The principle of payment is ability, or, more philosophically, equimarginal sacrifice, on the old Platonic principle that the best state is that which is likest the individual, and that the citizen should pay to the national house-

keeping on the same scale as he pays to his own private housekeeping. (2) In addition to these, certain other services are given over to the Government, central or local: they are made monopolies, and the products are sold at a non-competitive price. Such are the Post Office and Telegraph services, and in many cases gas, water, and tramway service. It is with this second class that we are concerned here, and regarding them three points must be emphasised.

The first is that the reason why these services are reserved to Government is certainly not that they can be rendered more cheaply by Government. It is, indeed, a debatable point whether they can be; where competition is not allowed, this must remain a matter of opinion. They are always reserved for some ulterior reason of public interest—some interest which might be imperilled in the conflict of private competition.

The second is that, in such cases, the Government services are general services: they are provision, on the basis of the taxpayers' or ratepayers' security, of commodities and services used and enjoyed by the great majority of the citizens.

The third is that in these services, so far as I am aware, there is no precedent for the Government selling to one class at a cheaper rate than it sells to another, on the ground that the class in question 'cannot afford it.' The poorest man pays a penny for a stamp; the richest citizen of Glasgow pays no more than a halfpenny for a car-stage.

But in the limited proposal we are now considering, what is being advocated is Government provision of a certain commodity for one class alone, and the ground taken undisguisedly is, that Government can provide this commodity more cheaply than private enterprise can, and that this class cannot afford more. It is not, indeed, proposed that the Municipality should rent at one price to the richer and another to the poorer tenant; but it is proposed that the Municipality should rent to one class at a rate which the other classes cannot possibly enjoy.

I do not think the problem can be understood, or its gravity estimated, till it is grasped that here the Municipality—the public trustee—is asked to give consent to a new principle and precedent for spending public money. Take the argument in its concrete form in Glasgow. Owing to (*a*) increased accommodation and conveniences, occasioned chiefly by statutory enactment; (*b*) increased cost of construction through the rise in wages and in the price of material; (*c*) increased cost of maintenance, not only owing to the rise in wages, but owing to the frequent abuse and destruction by careless tenants of the expensive fittings which modern science demands; (*d*) increase in landlords' taxes; (*e*) increased value of land, especially in the centre of the city—it seems that houses of one and two apartments are not being built to let at less than 6*l.* and 9*l* respectively, as against 5*l.* 5*s.* and 8*l.* 10*s.* in 1891. It is represented that there is a class of wage-earners who cannot pay these rents. It is asserted that, in virtue of its advantages, the Municipality can build and let such houses at 4*l.* 10*s.* and 8*l.* respectively, and it is stated, without more ado, that it is bound to do so.

There are two propositions here which cannot be allowed to pass without examination: the first is that there is a class which cannot afford the higher rent; the second, that this is a valid reason for the Municipality providing them with a lower one.

(1) Somewhat to the surprise of the Commissioners, it was given in evidence that, while wages generally have risen, there are labourers in Glasgow who are not earning more than 17*s.* a week—and these not casual labourers, but able-bodied men, in regular employment, and of ordinarily steady habits. To such a class sixpence a week is undoubtedly a serious consideration, and, although one might be inclined to ask if the sixpence could not, with great advantage to themselves and their families, be taken off the conventional necessaries of drink and, perhaps, tobacco, the point need not be pressed. My reason for doubting if even this class 'cannot afford' sixpence a week extra for a house is that one of the causes, perhaps the principal one, why such men earn only 17*s.* is that they live in conditions which lower health and efficiency, and make them inefficient and unreliable workers. I fully acknowledge that such people could not pay sixpence extra for the rent of a slum such as they are occupying, but I cannot forget the 'productive

value' of the modern higher rented house. It seems to me that fresh air, and quiet sleep at nights, and surroundings which would react on the character and conduct of the person on whom so much depends—the wife—might easily add far more than sixpence to the earning power of the household.

There is, unhappily, a class to whom this does not, directly at least, apply There are thousands of workers whose wages are not 17*s.*, but an average of 12*s.*—regular workers, and workers who could not take sixpence off their liquor and tobacco for the reason that they neither drink nor smoke. I mean women workers. And to these, I submit, a good house would have a greater 'productive value' than to men, for they are more subject to the illnesses and little ailments and depression which dock their wages by hours in the day and days in the month. So far as I can see, they are outside the housing question altogether, from the fact that they could not afford an independent house even at the lowest municipal rents. They must remain in the family as subsidiary wage-earners, or club together, or lodge.

(2) But assuming the very strongest case, that there is a class of unfortunate people who absolutely cannot afford to pay sixpence a week more, I should still say that this in itself is no reason why the Municipality should build. To supply them with houses under the market rate would be to introduce a new precedent and principle into Government industries which would lead us far. It would be using the credit of the entire body of the ratepayers to subsidise one small class of them; it would be, in essence, similar to the old legislation which kept down the price of bread when the harvest was bad, without the extenuation that such a measure kept down the price to everybody. It would be a rate in aid of wages. And if there is any lesson to be learned from the bitter experience of a century ago, it is that the evil of a rate-in-aid is, not so much that it punishes those who have to subscribe to it, as that it punishes those who receive it, in that it effectually prevents wages from rising.

The employer in towns has certain economic advantages over his rivals outside. He is at a centre of supply of all the agents of production and at a centre of demand for his goods. The play of competition balances this by imposing on him in general the charge of higher wages—a consequence and possibility recognised by the trade-union practice of fixing the standard wage slightly higher in town than in country. Unfortunately there is in all large cities a class who, from physical and mental disqualifications, from want of education and technical opportunity, and from want of organisation, must take very much the lowest wage which will keep them in life and moderate animal efficiency; and this class tends to be in over-supply from the fact that misfortune drains into it the failures of all the other classes. The existence of this class is a public misfortune; their low wages are not only bad of themselves, but they go to the very root of the future of labour, in that they prevent the children from getting out of the class. Rising rent, the natural effect of a large population and great business premises competing for a limited area of situation, is the healthy deterrent of the abnormal influx of such labour. For a Municipality to give these unfortunate people houses sixpence a week cheaper is to allow of them accepting sixpence a week less of wage than the circumstances would otherwise force the employer to give. It is not, of course, that employers, taking advantage of the helplessness of this class, would deliberately force their wages down by sixpence. It is that, in the present highly specialised organisation of industry, unskilled labour is in less and less demand, while, from the circumstances mentioned, it tends to be in over-supply; and this surplus labour offers itself for any wage that will keep it alive. As Mr. Booth says, 'the poverty of the poor is mainly the result of the competition of the very poor.' To deny such a causal connection between wages and public subsidies on the ground that it is 'only sixpence a week,' or that 'people do not come into cities because they can get cheap houses,' is like refusing to believe in natural law because one cannot actually see the minute movements which constitute its operation. If, then, it becomes known that, in addition to the other attractions of a city, good houses at slum rents are assured to everyone who is poor enough, it seems to me inevitable that this will further tempt the influx of unskilled

labour—and, unhappily, farm labour, skilled in its own fields, becomes unskilled when transferred to the streets and factories.

This, then, being the general argument against municipal building and owning of houses for the poorest classes, I go on to consider if there may not be circumstances in the evolution of a city which may justify the relaxation of the principle. Glasgow again affords an object-lesson. If the houses which are a danger to public health, as hopelessly insanitary, are pulled down; if 'back lands' and obstructive buildings are demolished; if the houses which are by law pronounced 'illegal' and cannot, from their structure and situation, be altered, are closed; and if the overcrowding laws are put sternly in force, something between 15,000 and 20,000 persons will be turned out, and will not be able to find houses at rents such as they were paying—for these measures will practically root out the low-rented houses in Glasgow. Many of the 15,000 or 20,000, no doubt, are well-paid wage-earners who will be the better of being forced into higher-rented houses; many of them, again, are dissolute and drunken persons who should be 'hustled' from pillar to post till there is no room for them among honest people. But many of them, in all probability, are respectable persons who, from the causes already mentioned, have come down to the 17*s*.-a-week level. What are these people to do? Granted that the low-rented slum property should never have been allowed to come into existence or continue; granted that the best thing that could happen to such labourers as a class is that it should be made impossible for them to accept these low wages; still it is a very drastic thing to take away the patient's bed in order to force him to walk.

Here I am chiefly impressed by two things. The first is that it is municipal inaction and municipal action which are responsible for the hardship.

(*a*) It is by no fault of their own that the people to be dispossessed are in occupation of these low-class houses. The Municipality for years allowed these houses to come into and remain in existence, and, to that extent, the Municipality is responsible for the low standard of life which allowed the tenants to take the low wages.

(*b*) It is to a great extent new municipal requirements that have made it impossible to build houses to be let at the old rents. To mention only a few of these: each adult must have 400 feet of air space, which means larger apartments; there must be ample sanitary appliances, involving expensive plumber-work; there are provisions for thickness of walls and solidity of construction, which many builders declare quite unnecessary.

The second is that, on its way towards conferring a great public benefit, this municipal action is likely to inflict serious hardship on a class who are least of all able to bear it. It is a recognised principle, in the science of public finance, that the charge of any general public benefit defrayed from rates or taxes should be spread over the citizens in proportion to their ability. In the present case, we have a great beneficent measure of public health by which all the citizens will gain, and in quite indeterminate measure; and, although this is not defrayed from the rates, by parity of reasoning it seems to follow that one class, and that the least able to bear the burden, should not be made to bear the heavy end of it. Granted that, by the operation of ordinary economic law, wages will ultimately rise to cover the higher rent demanded by private enterprise, and granted also that the houses at a higher rent have a 'productive value' which will itself enable the tenant to pay more rent, in virtue of giving him immunity from sickness, depression, low vitality, and bad neighbours, still this operation takes time, and, till time is given for the economic forces to work, there will be great hardship.

There is, besides, an opportunist argument. There seems to be no doubt that the magistrates and responsible officials have hitherto shrunk from carrying out their powers because of the hardship that will be entailed. If this hardship can be avoided, there will remain no excuse and no reason for not proceeding rigorously with measures which otherwise might be somewhat extreme.

It is in consideration of these circumstances that the Glasgow Commission has recommended the erection by the Municipality, up to the extent of certain powers

possessed by them under special Acts, of tenements of one- and two-apartment houses, to be reserved exclusively for respectable people of the poorest class, preference being given to those dispossessed; such houses to be situated, if possible, near to the area of dispossession, and to be under carefully selected caretakers.

It will be seen that the amount of building recommended is limited, the money which the Municipality can spend under the Acts referred to being fixed and known. One would have liked, perhaps, that it should have been more rigorously limited. It would have been quite possible to take a rough census of the people dispossessed and build houses only to the number necessary to accommodate those who really suffer by the dispossession—the respectable poor at low wages. And what one would have liked, besides, was the clear laying down of the principle that this is an exceptional measure, due to an exceptional set of circumstances which can never occur again if the Municipality lives up to the powers it has sought and obtained from Parliament. Insanitary and illegal houses should never again be allowed to come into existence. Overcrowding can now be rigorously kept in check. It will clearly be the fault of the Municipality if such a problem recurs.

But, on the whole, the recommendation seems to me a wise one. It escapes the chief objection, that of tempting an influx of new unskilled labour. It does not add to the supply of cheap houses, but merely fills the gaps which municipal action has itself caused. It has not advised the drastic step of compelling a rise of wages by suddenly making it impossible for a class to live without paying higher rent—which would have been accompanied by the serious danger of driving many over the verge of subsistence—but it does not give any occasion for still further lowering wages, and there is the positive good that the houses to be provided are such as naturally make men and women better workers, who will command a gradually increasing wage.

There is, indeed, I am afraid, a 'loose end' in the result of the Commission. To its subsequent regret it was confined, by the limitations of its remit, to the consideration of housing within the city boundaries, and Greater Glasgow is growing more rapidly outside these boundaries. I said that the problems of Glasgow grew up because the city refused to look forward and lay down the lines of its growth. Unhappily, that course is still forced upon it, in that it has no control over the operations of its suburbs. Everyone knows that, in the near future, Glasgow must extend its jurisdiction and responsibilities. There is too much reason to fear that, when that time comes, the city will fall heir to the same problem as it has now to face—insanitary property and ill-planned districts. This is a problem of all growing cities, and, in my opinion, a most urgent one.

But this is not the whole of Glasgow's answer to its Housing Problem. The municipal houses are to be reserved for the respectable poor. What about the non-respectable—probably the majority of those who will be dispossessed? So far as I can see, the criminal and the dissolute have no claim on the community so far as regards housing. They must be 'hustled;' that is, life must be made as difficult as possible for them, till either they can find no rest for the sole of their foot among decent people, or are driven to reform. And this hustling will be done to a considerable extent when all the insanitary and illegal houses are done away with, when the Corporation houses are closed against them, and when private enterprise is assisted to get rid of them, as the Commission recommends, by more stringent laws against the habits of disorderly and destructive tenants, and by more summary powers of ejectment. But there are many who are neither criminal nor hopelessly dissolute, and yet cannot rise simply because they are down. They have lost their character; money cannot buy them a decent house because they have no factor's line or other guarantee that they are fit for the possession of it. It is this class, perhaps, that will be most heavily hit by the dispossession, and for them also it seems that some compensatory provision should be made by the Municipality. And this seems also in the interests of the community, for, if these people are not lifted up, they will be driven down.

Hence the recommendation of the Commission that 'an experiment should be made in the erection of a building or buildings for those who, while unable to

show any factor's line or other certificate, are willing to submit to necessary regulations as to cleanliness, respectable living, order, and punctual payment of rent, with the view of rehabilitating their character, and in time qualifying for a better house; such houses to be of the plainest construction, with indestructible fittings, and capable of being quickly and efficiently cleansed.'

It is avowedly an experiment. The difficulty is not to provide such houses, but to get the proper people to go into them. If any social obloquy is allowed to attach to these houses, the proper people will not go into them. But it is an experiment to which I think everyone will wish Godspeed. At any rate, it removes the last excuse for not going forward systematically, rigorously, and continuously with the renovation, closure, demolition, and prevention of overcrowding which are the beginnings of any solution of the Housing Problem.

The following Papers were read:—

1. *Tests of National Progress.*[1] *By* A. L. Bowley, *M.A.*

In a paper read at Southport the author suggested tests by which the national progress in economic well-being might be measured over any defined period. The necessary statistics covering the forty years from 1860 are now offered. The test measurements are of wages, employment, income, prices, and consumption. An index number is formed for average wages, allowing for irregularity of work. A new estimate is made for income, subject to income-tax, allowing for all the changes in methods of assessment, and including estimates for income unduly escaping tax; and a special method is employed for dealing with the changes in the exemption limit. An index number is them formed for average income. The two series of index numbers, for wages and income, are found to have very many points of resemblance; both show a rapid rise from 1860 to 1874, a fall to 1878, two fluctuations to 1893, and a rapid rise to 1900. The series are then combined, and allowance is made for the fluctuations of prices; the resulting index number shows a nearly regular progress throughout the forty years. The index number for consumption of common necessaries also shows fairly regular progress. It is contended that the series used are consistent with and support each other, and that there has been steady progress decade by decade, though perhaps less rapid and continuous than the final series suggests. Other tests are considered, and rejected because of their incompleteness.

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2. *A Moot Point in the Theory of International Trade.* *By* Professor F. Y. Edgeworth, *D.C.L.*

Whether under circumstances not very extraordinary, with a probability worth taking into account, the abandonment of Protection might lead to a permanent diminution in the numbers and income of the working class? This question, raised by Sidgwick, was discussed with special reference to Professor Bastable's observations on the disputed point in the Appendix to his 'Theory of International Trade.'

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3. *The Influence of Agricultural Improvements on Rent.* *By* Professor A. W. Flux, *M.A.*

The reprinting of Malthus' pamphlet on 'The Nature and Progress of Rent' has suggested the comparison of his conclusions with those suggested by a study of rent diagrams. In this paper the integral diagram was employed, that is, the abscissæ represent outlay on cultivation; the corresponding ordinates represent the total return secured.

[1] Published in the *Economic Journal*, September 1904.

Three cases were examined: (1) Effect of a change of value of agricultural produce; (2) effect of changes of method, increasing in the same proportion the return to all outlay on cultivation; (3) effect of changes which increase the return to some scales of cultivation and diminish those to others. Decreasing returns were assumed throughout.

In the first case a rise of price yields increase of rent generally, though on the question of the proportion which rent bears to total produce the result may vary with the intensity of cultivation. The second case is but the first under another form. In the third case there cannot be stated any general rule as to the direction of change. The combination of the second and third cases will give the most general case. The conclusion that improvements tend in all cases to decrease the proportion which rent bears to total produce, appears not to be supported by the presentation of the case in diagrammatic form.

FRIDAY, AUGUST 19.

The following Papers were read:—

1. *The Incidence of Protective Duties on the Industry and Food Supply of France. By* Yves Guyot.

From the inquiries made by 'L'Office du Travail' on wages and hours of labour, and from the publications entitled 'Bordereaux de Salaires,' the following is the percentage, in numerical order of importance, of the two chief industries of France:—Labour employed on modes, lingerie, garments, 20·47; labour employed in textile industries (cotton-spinning and weaving, wool-combing and cloths), 14·17.

Group I. includes 1,340,000 persons. All Customs duties which fall on textiles, and therefore raise the price of their primary material, by striking at their export, keep down the rise of these industries, and are one of the causes of a fall in wages.

The three years' annual average of exports of clothing and lingerie, before and after the tariffs of 1892, was:—

	Francs
1889–1891	120,300,000
1894–1896	93,300,000

a fall of 22 per cent.

The average rose again, 1900–02, to 134,100,000 francs; a rise, compared with 1889–91, of 11 per cent. In the case of sewed lingerie the following is the position of its export:—

	Kilogrammes	Francs
1889–1891	1,080,000	54,600,000
1901	493,000	20,400,000
1902	489,400	19,800,000

Some woven stuffs, such as Irish linen, cannot be produced in France. The Customs duties prohibit their entry, and the manufacture of a certain number of articles has to be left to foreign competitors

It is the same in the case of the export of men's made-up garments:

	Kilogrammes	Francs
1877–1886	1,642,000	38,367,000
1902	1,117,000	17,179,000

The export of made-up silk garments for women has increased; this, however, is not due to protection, but to the increase in wealth of certain foreign nations.

Cotton woven goods, raw, dyed, and printed, are worth, as exports, from 3 francs 40 centimes to 5 francs per kilogramme; linen woven goods, from 2 francs

80 centimes to 8 francs 89 centimes. These goods, made into shirts, collars, and sewed lingerie, are worth 40 francs 60 centimes per kilogramme.

The export prices of silk woven goods have been valued for 1902: Plain, 75 francs; figured or brocaded, 88 francs; mixed, 39 francs; figured, 42 francs the kilogramme. Made-up silk garments for women are valued at 389 francs 50 centimes. Whence this difference unless it comes from the fashion given to these stuffs? And the larger part of this difference between the price of the primary material and that of the garment represents wages.

In France the woollen industry has a plant whose producing power is double the amount consumed. The trade has been stationary now for some years. What is needed here is an outlet, not protection.

The textile manufacturers who never cease to demand protection are the cotton-spinners (who also weave, or drag the cotton-weaving in their train) and the linen-spinners. The cotton-spinner earns 2 francs 50 centimes, where the woollen-spinner earns 4 francs 50 centimes. The number of cotton-spinning spindles in 1891 was 3,779,400. In 1902 it was, according to M. Méline, 6,150,000. The consumption of raw cotton, 1889-91, was 143 million kilogrammes; in 1898–1902 it was 178 million kilogrammes. This increase of 24 per cent. is 38 per cent. less than the increase of the plant, which is 62 per cent., and this takes no account of the increased fineness of the numbers spun.

All the cotton and linen spinners complain of over-production. They are reduced to running short time and shutting down, and very often to clearing off their stock abroad at a loss. Protection has called forth an artificial demand for labour. Wages are lowered by the irregular employment. It has thus brought about a series of crises.

The silk industry has need of freedom. Nevertheless, it is tributary to the duties which have been put on silk yarns and on cotton yarn. Of 3,712,000 kilos. exported in 1902, 2,024,000 kilos., *i.e.*, 54 per cent., are mixtures which pay the exorbitant duties that burden the finest numbers of cotton yarn.

It may thus be seen that the clothing and lingerie industries pay quite a special tribute to the cotton-spinning industry, which represents 50,000 workers, as against more than 1,400,000.

The silk industry is similarly tributary to it.

The metal industry is divided into two groups: the one representing 0·88 per cent. in industrial importance, the other 9·55 per cent. In the first are thirty factories of over 500 workers, representing 50,000 workers. (The calculation is exaggerated, as not fifteen of these factories produce pig iron and steel.) The second group, with 650,000 workers, counts for 10 per cent. in industrial importance. This group, which comprises builders and smiths, uses iron and steel as primary material, and pays tribute to the minority which produces them.

The legislation of 1893 had recourse to a system of premiums for naval construction; if it had not been that the vessels of subsidised postal companies were bound to be built in France, this legislation would have done away with the building of steamships. The building of such ships represented, in 1900, 10,396 gross tons; in 1901, 10,190. The building of sailing ships was 78,903 tons in 1900, and 59,320 in 1901. Between 1893 and 1902 the State had paid to attain this result 183,796,000 francs, not counting about twenty-six millions per annum of postal subsidies.

In 1884, in order to justify the sugar legislation, M. Méline pleaded the interest of the workers. Now the number of these workers was 43,896 in 1884–85, and 40,982 in 1902–03. The total wages during the first year of the legislation were 15,539,000 francs; during the last, 13,115,000 francs; a reduction of 2,424,000 francs. To attain this result, the Treasury had paid out to the sugar manufacturers, who numbered no more than 332 in 1902, the sum of 1,109 millions, exclusive of 168 millions as bonus to the colonial sugar industry.

These facts prove that the industries which are most important, both as regards the number of persons employed and the returns, pay tribute to industries which employ but a limited number, with a much smaller return.

II.

The food supply of the Frenchman is heavily hit. In 1796 the celebrated mathematician Lagrange, in order to estimate the food ration of France, took the soldier's ration as typical; then, taking account of the lesser needs of women and children, he reduced the population by one-fifth. The military ration of those days was 28 oz. ($1\frac{3}{4}$ lb.) of bread and $\frac{1}{2}$ lb. of meat. I take, as he did, the actual ration of the soldier in times of peace: bread, 1 kilo.; meat (including bone), 300 grammes. Atwater,[1] in his learned inquiries into the food supply of the United States, calculates the quantity for a woman at 80 per cent. of that necessary for a man; for children of two to five years, 40 per cent.; for children of nine years, 50 per cent.; for children of thirteen years, 60 per cent. and for children of fourteen years, 80 per cent.

I take for my hypothesis a figure less than the actual one. I assume that the allowance necessary for a woman is three-quarters that for a man; that the allowance of an old person can be put at that of a woman; that the allowance of all children under fifteen years is three-quarters that of a woman; and leave out of account altogether the food necessary for children under one year.

Under these conditions the total food allowance for every 1,000 inhabitants would be: Men, 300; women and old persons, 315; children, 195; total, 810. In round figures the total adults' allowance comes to four-fifths that of the whole population. Recent returns and observations on the proportion of the food supply give exactly the same figures as those reached by Lagrange.

I go, however, still further, and reduce the one-fifth to one-fourth, and, supposing, in order to simplify the calculations, that I take the population of France at forty millions instead of thirty-nine, I have a total of thirty millions of rations instead of 30,200,000.

By the duty of 7 francs on corn, 20 francs per quintal live weight of beef, 25 francs per quintal live weight of sheep (which brings the duty on the net weight of butcher's meat, including bone, up to 35 francs), the landed proprietors have secured the monopoly of supplying bread and meat to the population of France. I shall examine the extent to which they do this.

I shall take the old formula; that 100 kilos. of corn = 100 kilos. of bread. According to the decennial Agricultural Inquiry of 1892, forty-three out of eighty-two departments do not produce enough for their own support. In 1902 the wheat harvest was 8,814,000 tons; the seed sown required 1,050,000 tons. I do not deduct the 500,000 or 600,000 tons used for industrial purposes. There remain, for purposes of food, 7,800,000 tons Now 360 kilos. of bread multiplied by 30,000,000 rations come to 10,800,000 tons. This leaves a deficit of 3,000,000 tons of wheat, or 29 per cent. Potatoes and vegetables are poor substitutes to fill up such a gap.

With regard to meat, as the annual agricultural statistics do not give the average production of butcher's meat, I shall take the figures supplied by the Agricultural Inquiry of 1892 (p. 304 and onwards).

Net weight in meat of home-grown animals slaughtered: Beef, 720,810 tons; sheep, 125,868 tons; pork, 461,600 tons; total, 1,308,000 tons. We have to provide for 3,240,000 tons. The deficit is, therefore, 1,930,000, or 59 per cent. In a word, where 100 kilos. of meat are required, we have 41. Even with the addition of 300,000 tons of fish and 173,000 tons of eggs, the deficit is between 40 and 50 per cent. In short, in France we have but half of the animal nourishment required, and the price continues to rise in the Paris market.

Although, since the duties on corn, no wheat harvest has come up to that of 1874, when the duty was 0·60 centime per 100 kilos., let us assume that, without the duty of 7 francs, the loss of corn would have risen to 350 millions per annum; let us assume that, without duties on meat, it would have been another 350; in all, 700 millions. The protective legislators have not wiped out that loss; they have relieved the proprietors from it and have laid it on the consumers of bread and meat.

This transference has been made to the profit of the proprietors of those of the

[1] *Dietary Studies in New York City*, 1896-1897.

168,000 agricultural holdings of more than 40 hectares which produce wheat (these proprietors own 10,140,000 hectares of arable land and 4,033,000 hectares of pasture); to the profit also, although in a lesser degree, of the proprietors of the 771,000 agricultural holdings of from 10 to 40 hectares (these own 8,363,000 hectares of arable land and 2,388,000 of pasture). As for the 4,852,000 proprietors of land of less than 10 hectares, they have but 3,339,000 hectares of arable land and 1,929,000 of grass land to divide among them.

III.

Who, then, has an interest in Protection in France? According to the 'Recensement des Professions,' established in 1896 by the Minister of Commerce and Industry, the agricultural industry, which in 1866, with a duty of 0·60 centime, represented 52 per cent. of the active population, does not now represent more than 47 per cent. in spite of the duty of 7 francs; indeed, the great majority of the farmers is not interested in Protection. Agricultural establishments which number only from one to four wage-earners represent 92 per cent. of the whole. They have but a slight interest in the duty of 7 francs. There remain, then, 8 per cent. of the agricultural class, many of whom do not grow corn, or, at any rate, very little.

Industry represents 35 per cent. of the active population, but the little industries which work up secondary material have no interest in Protection; and the number of establishments employing no more than one to four wage-earners count to 85 per cent.

Commerce accounts for 5 per cent.; and large as well as small commerce is interested in freedom of exchange, as are also the banks. The same may be said of the liberal professions, which count for 7 per cent.

Who, then, are interested in Protection? At most 8 per cent. of the agricultural class—*i.e.*, about 3 per cent. of the whole active population.

With the exception of the small group of cotton and linen spinners—so poorly paid that they almost believe their fate depends on Protection—the interest of all the rest lies in Free Trade, which would liberate the industries that are likely to live from the tyranny of the industries which only exist by favour of Protection.

What do the workers in cotton-spinning factories number? About 40,000. Add if you will the weavers, many of whom, however, would be interested in procuring their yarns free, and we have 160,000. If we include the 50,000 metal-workers (though a certain number of the factories which employ them would be interested in procuring pig-iron, iron, and steel at the lowest prices) and the 20,000 tanners (whose industry also has more to gain by Free Trade than by Protection), even then, out of an industrial population of 6,374,000 persons, these 200,000 do not represent more than 3 per cent.

But men of independent means, retired men, members of the liberal professions, and officers are interested in living cheaply. The soldiers, too, are concerned in the cheapness of their daily ration. Not 5 per cent.—not one person in twenty—can be found who is interested in Protection.

Such is the state of affairs in France. It is sufficient to study them closely to see the errors of Protection—the heavy burden which it imposes on the majority, one part of which can only escape its weight by that involuntary asceticism called misery. There are leagues in France against tuberculosis which make noise enough, but the hygiene of the beef-steak is forgotten, and it is that of which the working man is mostly in need, especially the working man in France.

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2. *The Effect of Protection on some German Industries.*[1]
By Professor W. Lotz.

The programme of fiscal reform which from 1879 until now has ruled German politics is:

(*a*) Protective duties upon the importation of food;

[1] Published in the *Economic Journal*, December 1904.

(*b*) free importation of raw materials for the use of industries;
(*c*) protective duties upon the importation of articles manufactured and partly manufactured.

Solidarity of the protected national interests was proclaimed. Effective protection of national industries, however, cannot be granted but at the expense of other national interests. Leaving on one side the questions of the effect on consumers, and whether all agriculturists have got an advantage by the protectionist system, the author deals with the effect of German Customs duties, railroad rates, and export bounties, *i.e.*, of the whole system of 'new mercantilism,' on German industrial classes. Statistics show that production and exportation have increased; but, nevertheless, experience and recently the evidence taken by the Imperial Cartell-Committee prove that some very important branches of German industries suffer seriously from the protection accorded to others.

Raw materials are universally regarded as unfit subjects of Protection. Increased cost of raw materials would prevent the manufacturer from exportation. But free trade in materials gave a special advantage only (*a*) to those producers who sell in a protected market articles partly manufactured, as pig-iron, steel, cotton 'yarns,' &c.; (*b*) to combined or mixed concerns which own coals, iron ores, furnaces, &c., and produce finished articles from their own or from imported raw materials.

As far as the mine-owners and the producers of articles partly manufactured have formed syndicates, they endeavour to force upon their German customers higher prices than Free Trade would permit. As far as they practised 'dumping' goods on foreign markets, they sold German unfinished articles at preference prices to the foreign competitors of the German producers of finished articles.

Therefore, those German producers of finished articles, *e.g.*, machines, shoes, needles, glassware, hosiery, who must buy the articles partly manufactured from German monopolists, or from abroad as dutiable commodities, get no advantage from the free importation of raw materials. Having developed to a stage in which they cannot exist without exportation, they would not be endangered by absolute Free Trade. Unable to form such powerful syndicates and draw so much profit from the internal market as the protected monopolists, whose customers they are, the manufacturers of finished articles cannot practise 'dumping' in a great style. On the contrary, their regular exportation is endangered (*a*) by dumping done abroad in their materials; (*b*) by the internal and external competition of combined concerns which do not buy any protected articles, but produce all materials themselves; (*c*) by the effect of duties on food upon the cost of living of their operatives; (*d*) by the general check to exports resulting from protective policy.

Some producers of finished manufactures enjoy special privileges by which the pernicious effect of higher national prices of unfinished articles is diminished. Shipbuilders are by special clauses entitled to get what they need at Free Trade prices; some industries of manufactured iron get from the coal, iron, and steel syndicates private exportation bounties which, however, are never higher than the enhancement of price due to Protection and syndicates. Some industries get Government drawbacks; but even these are not better off than under Free Trade, and the other producers of finished articles who do not produce their own materials are the more injured the more Protection and syndicates favoured by it make progress.

The specialisation of industries cannot be developed so intensively as under Free Trade. The chief effect of Protection in the present stage of development is as follows: countries of old civilisation can never in the long run compete successfully with the new world, by protecting industries mainly dependent on natural facilities at the expense of industries whose success depends on the intelligence, skill, and training of workmen. By favouring agriculturists and the producers of bulky industrial articles partly manufactured, the countries of old civilisation deprive their best champions, the manufacturers of finished articles which would flourish under Free Trade, of the indispensable advantage of buying in the cheapest market.

Considered from an evolutionist point, the present state of Protection of bulky

and syndicated industries tends to deprive Germany and other countries in an analogous position of the best natural advantage which they possess in competition with the other parts of the world, *i.e.*, of superiority in the cheap and skilful production of finished articles.

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3. *Free Trade and the Labour Market.*[1] *By* Professor H. DIETZEL.

In the controversy as to how the fiscal system influences the stability of the labour market two main arguments come to the front. The Protectionists assert that from Free Trade arises (1) the danger of dumping by foreigners; (2) the danger that crises may break out at home, and that therefore the labour market fluctuates more under Free Trade than under Protection. Both ideas are fallacious.

(1) The Dumping Argument.—There are two kinds of dumping: intermittent, occasional dumping, consequent upon over-production abroad; and regular, deliberate dumping arising from the ability of Cartells in Protectionist lands to sell in other countries at low prices.

(*a*) Over-production dumping is an evil: it creates great disturbance in the labour market of the country. It is not, however, abolished by Protection—at least not by a system of low duties such as now exists in Germany, and is planned for England. Under Free Trade the danger is no greater, in spite of the fact that there are no duties to be reckoned with; for a Free Trade country has natural protection in that the price of wares which it produces, and for which it has to fear foreign competition, remains lower there in normal circumstances than anywhere else. In Protectionist lands the duties must indeed be reckoned with; but from them the price of home productions is also higher. If in protected countries prices are higher than in Free Trade countries, yet they are exposed, to exactly the same extent, to the dangers of dumping.

(*b*) Trust dumping, since it is chronic, presents no evil from the standpoint of continuity. It does not disturb the labour market now and again, but rather causes the working power in the home country to be differently invested than if it did not exist. If foreign Cartells sell sugar, iron, &c., permanently to England at prices that are lower than those at which the English *entrepreneur* can sell, this is economically profitable to England, for she can buy those goods from the foreigner with less national work than would be expended on it if it produced them at home. Whether the greater cheapness comes artificially or naturally does not matter.

Some industries may be destroyed or handicapped through free competition, but others will flourish the more.

(2) The Crises Argument.—England was formerly the classical land of the crisis. According to the ideas of the Protectionists, this fact had its cause in the interweaving of England's industry with the world's industry. The world-market, they thought, must be far more fluctuating than the internal market. The Free Traders maintained, on the contrary, that it was the corn-tax *régime* that was subject to this accusation. After the fall of all barriers the employment of labour would become much more steady. This prophecy has been entirely fulfilled; no land has had less to suffer from industrial fluctuations than England.

The result of the corn-tax *régime* was that English industry rose and fell with the ups and downs of the national harvests. The result of the removal of that *régime* was that English industries rose and fell with the rising and falling of the world's harvests, which was much more regular than the national; thence the condition of English industry became more regular.

Free Trade works favourably for continuity; Protection the reverse.

(*a*) The higher the protective tariffs the greater the danger that an extraordinary demand may lead to inflation, over-production, and crisis. Safe from foreign com-

[1] Published in the *Economic Journal.*

petition, the home *entrepreneurs* can take full advantage of the inflation; prices mount vigorously only to fall as rapidly. With Free Trade there is less danger of a crisis, because there is less danger of a boom and over-production.

As soon as in a Free Trade country prices rise above the ordinary level, foreign competition moderates them by import. The 'inlet valve' operates. Free Trade tends to prevent crises.

(*b*) The higher the protective tariffs the greater the danger of acute and lasting crises. For in order to throw off the superfluous goods into other countries, a greater fall in prices is necessary. Because of the high tariff the home prices can differ greatly during the time of inflation from those in the world-market.

With Free Trade inflation and over-production can equally have place; but the home prices cannot differ much from those in the world-market, and as soon as reaction comes superfluous goods can be exported. The 'outlet valve' operates. Free Trade tends to mitigate crises.

For these reasons, such countries as Free Trade England and Germany, with their moderate tariffs, were not subject to such violent industrial fluctuations as were the United States and Russia. The inflation was less violent, thanks to the increase of imports that was induced; the reaction was less intense and less enduring, thanks to the accompanying increase of exports.

The return of Protection to England would mean the return of crises.

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4. *Economic Theory and Fiscal Policy.*[1] *By* L. L. PRICE, *M.A.*

Sir Robert Giffen has recently declared that the 'argument for Free Trade generally' appears to be 'complete both theoretically and experimentally,' and Professor Smart has similarly observed that 'Free Trade is the economist's policy.' These absolute statements do not accord with the impression produced on the mind of the writer of this paper by the recent literature of economic theory. He would in any case deprecate the attempt to close discussion by an appeal to authority, but he would also question the correctness of the appeal in this particular instance.

The large abstention of historical economists from the condemnation pronounced by their colleagues on Colonial preference possesses some significance; for the instinct and habit of the historian set him on his guard against the pretensions of a theory or the claim of a policy to universal applicability. A manifesto issued in August last made the writer of this paper hesitate whether it was worth while to pursue the theoretical inquiries with which for some years past he had been mainly occupied. He was reassured by reflection, for he remained convinced that the theoretical argument for unqualified Free Trade was not 'complete.' This position may be established both by an examination of the particular theories of international trade and value and also by the more general considerations to which the greater attention will be paid in this paper.

Exclusive stress need not be laid on the argument that the fiscal policy of Free Trade is the surviving article of a general faith in *laisser faire*. It may be granted that Factory Legislation does not by itself justify interference with Free Trade. Or a broader, more convincing line of reasoning may be found in the disavowal of a universal rule and a resort to particular experience. Viewing the question from this standpoint, however, the reforming statesmen of the nineteenth century should be regarded as practical financiers primarily, and as economic theorists in a subordinate degree. Later experience seems to have shown that the simplification of the tariff was pushed beyond a point at which, with an increased expenditure, it can be retained; and similarly, in their reaction from the Mercantile System, they may have carried further than their practical sagacity would now recommend the principle of *laisser faire* in trading matters. For the absence of any

[1] Published in the *Economic Journal*, September 1904.

guarantee of the identity of the interests of the present and of the future and of those of the individual trader and of the community is a failing common to Free Trade and *laisser faire.*

Competition between individuals has, no doubt, been employed as a working hypothesis in economic theory from the days when Economics, as a science distinct from an art, originated with Adam Smith, and is still the assumption with which economists commence their reasoning; and so far Free Trade may with some excuse be described as 'the economist's policy.' But the convenience of a theory does not prove the correspondence to fact of the assumption on which it rests; nor does the useful theoretical hypothesis of competition between individuals exchanging their commodities demonstrate the practical expediency of a fiscal policy of Free Trade.

The prominence given to marginal factors has been a conspicuous feature of recent economics. It has scarcely been brought into very explicit relation with the theories of international trade and value. The use made of final or marginal utility by writers like Jevons and Dr. Cannan has concealed the gap between the interests of the present and those of the future in very much the same as it has been hidden in the common argument based on the necessary equivalence of imports and exports. But the whole conception of marginal factors as determining influences rests on the assumption of individual competition, while the section devoted in economic treatises to monopoly grows in bulk, and the place occupied by combinations in business practice becomes more prominent. The influence of monopoly on international trade has been recognised, but the more recent development of a formal theory of monopoly has been brought into no more explicit relations with this department of theory than those which at present attend the conception of the governing importance of marginal factors. Indeed, the general reconstruction of economic theory required by the substitution of monopolies or combinations for individual competition has not been fairly faced. Yet it is not easy to bring into accord with these new developments the determining influence of marginal factors. For combinations act by mass and not by separate parts, and are the negation of those infinitesimal additions and deductions which are suggested and implied in the conception of a margin. With the notion of individual competition, in general use as the primary assumption of economic theory, the theoretical argument for Free Trade has, on the other hand, been associated. Yet the power of Trusts testifies to the present influence of combination in this department of business practice, and some curious consequences follow from the new position taken by monopoly in theory and fact alike.

MONDAY, AUGUST 22.

The following Papers and Report were read:—

1. *The Economic Importance of the Family.* *By* Mrs. Bosanquet.

There are two points of view from which we may consider the economic function of the family; first, in relation to the supply and maintenance of an effective population; secondly, in relation to the particular industrial organisation of a given time and place.

From the latter point of view the function, perhaps even the importance, of the family group is apt to vary. Compare Le Play's description of the Famille Souche and other phases of organisation, where the family is the unit of production, and is held together by the industrial dependence of the different members upon each other, with the system under which each member of the family finds and carries on his work independently of the others. Both phases still exist, but the latter tends increasingly to preponderate; and it is probably this tendency

which has given rise to the opinion that the family is ceasing to be an important group in the community. This opinion, however, neglects the other side of the function of the family, that, namely, of regulating the quantity and determining the quality of the population. The intimate relations of family life are rightly regarded as being on a higher plane than what are ordinarily regarded as mere economic motives; nevertheless their importance from an economic point of view is quite inestimable. This importance may be considered under two headings: (i.) the family as a nursery for the best quality of human life compared with other possible institutions; (ii.) the family as maximising the economic strength of a people by grouping together those of different ages and capacities.

2. *Cotton-growing in the Empire.* *By* J. A. Hutton.

It is evident that during the last four years the consumption of cotton has been rapidly overtaking production, and at the present time many mills in England, the United States, and the Continent are running short time, entailing privations on the operatives and a wastage of employers' capital.

Two principal causes have contributed to this shortage. The first is a want of elasticity in the American crop, which amounted to $11\frac{1}{4}$ million bales in 1898, since which date it has averaged $10\frac{1}{2}$ million bales. The second cause is the large increase in the world's consumption, viz., about 400,000 to 500,000 bales per annum.

Although short time has been worked all over the world, the English spinners have suffered most. A certain amount of short time was worked in 1901 and 1902. In 1903 most of the Lancashire mills worked forty hours instead of fifty-five and a half for four months. In 1904 forty hours was worked from January to August with the exception of a few weeks, when the time was extended to forty-eight hours.

The crisis has been aggravated by the manipulations of speculators, who forced cotton up from $5\frac{3}{4}$*d.* to 9*d.* a pound. These manipulations have been accompanied by violent fluctuations, which have made legitimate business exceedingly difficult, if not impossible.

The principal remedy adopted so far is short time. It is not generally realised what a very costly remedy this is. The operatives suffer severely through decreased wages, the manufacturers' expenses are nearly as large, and in only a moderately sized mill running short time would make a difference of 100*l.* a week, or 5,000*l.* per annum. The kindred trades, such as dyers, printers, finishers, and distribution, must also suffer. There is also a decreased demand for the productions of other trades less closely connected. The receipts of the Lancashire and Yorkshire Railway Company for the first six months of 1904 show a falling off of 44,000*l.* as compared with 1903, and 70,000*l.* as compared with 1902. In fact, the result is widespread throughout the country. It is estimated that no less than 10,000,000 people are more or less dependent on the cotton trade. Mr. C. W. Macara estimates the loss to capital and labour in the cotton and allied trades through short time at 150,000*l.* per week.

There is no great hope of immediate relief. The evil would be mitigated if the market were free from the manipulations of speculators. Legislative measures have been suggested, but would be difficult to devise without doing more harm than good. Owing to labour and other difficulties there is little probability of the American crop increasing to over 12 million bales in the immediate future, so that large sources of supply must be found in other parts of the world to meet the normal increase in demand, estimated at 400,000 bales per annum. The solution of this problem is the *raison d'être* of the British Cotton-growing Association and similar bodies in France, Germany, and elsewhere.

The British Cotton-growing Association was inaugurated on June 12, 1902. A large amount of experimental work has been carried on, and it has now been decided to utilise the results of these experiments and to extend the work on a commercial basis.

The work of the Association is confined to the British Empire. In India, in conjunction with the Government, efforts are being made to improve the methods of cultivation, so as to increase the quantity grown and to improve the quality. Seed farms should be established for educational purposes and to supply selected seed for native cultivators. These should be nearly self-supporting. Seed and machinery have been sent to the West Indies and financial assistance has been given. Large quantities of Sea Island cotton, ranging in value from 11*d.* to 16*d.* a pound, have been grown, and there is every hope of a large cultivation being established. In Egypt Proper the Government and people are fully alive to the advisability of increasing the growth. In British East Africa and British Central Africa there is an excellent prospect, and the work is well advanced in the latter colony, and 3,000 bales of Egyptian cotton will be marketed this season. In British West Africa there is a large area—500,000 square miles—and a large population—10,000,000. Cotton equal to average American has been grown in large quantities, and there is no reason why the whole of West Africa--British and foreign—should not at some future date grow 20,000,000 bales of cotton. Seed has been supplied, experts been sent out, and seed farms are being established. It is felt that the best policy is to establish cotton-growing as a native industry, as the climate is unsuitable for Europeans. The British Cotton-growing Association have undertaken an enormous task, and have proved that sufficient cotton for Lancashire's needs can be grown in British possessions. Their work, if successful, will enrich the colonies and increase the demand for manufactured goods.

Addendum.

Abstract of Memorandum by Professor DUNSTAN.

As a rule cotton can be successfully grown in countries within a region 40° north and south of the equator, provided that the soil is appropriate and that the rainfall or irrigation is sufficient. Within this region the following British Colonies and Dependencies are included:—British Honduras, the West Indies, British Guiana, Gambia, Sierra Leone, the Gold Coast, Lagos and Nigeria, East Africa and Uganda, South Africa, Mauritius, the Seychelles, India, the Straits Settlements, the Federated Malay States, Australia, New Guinea, and Fiji. Egypt, Cyprus, and Malta must also be included.

Professor Dunstan went fully into the necessity of supplementing practical work by scientific investigation on the following points:—(1) Chemical analysis of soil, (2) rotation of crops, (3) selection of varieties most suited to the soil and climate, (4) educational supervision of native cultivation, (5) selection of seed.

He drew attention to the value of the scientific work which is being carried on by the United States, Egypt, Germany, and other countries, and strongly urged that experimental stations should be established in the various colonies under Government supervision, and that these stations should be co-ordinated with a central institution in this country, so that the work may be conducted on a general plan, and the information gained at each of the stations may be collected and made available for the benefit of all. At present no organisation of this kind exists, although a portion of the work is being conducted by the Imperial Institute in conjunction with the Colonial Office.

He then dealt very fully with the results so far obtained and the future prospects in different parts of the Empire, and it is most gratifying to find that with two exceptions the prospects are most hopeful and encouraging. These exceptions are the Straits Settlements, where the climatic conditions are unfavourable, and the Australian colonies, where the difficulty of obtaining cheap labour seems to render successful cotton cultivation an impossibility. His inquiries have extended from Borneo on the one side to the West Indies on the other, and from Malta to South Africa.

3. *Report on the Accuracy and Comparability of British and Foreign Statistics of International Trade.*—See Reports, p. 302.

TUESDAY, AUGUST 23.

The following Papers were read:—

1. *Changes in Nominal and Real Wages in Belgium.*[1]
By Professor E. MAHAIM.

I. *Nominal Wages*—Estimates of changes in nominal wages are shown in Table I. They are arranged on as nearly as possible the same basis as similar estimates by Mr. Bowley, read to the British Association in 1895 and 1898.

TABLE I.—*Nominal Wages in Selected Trades in Belgium for Various Years, the Wages of Agricultural Labourers for* 1895 *being taken as* 100, *and Weighted Average for all these Trades.*

—	1830	1840	1846	1856	1874	1880	1890	1891	1895	1896
Cotton	—	—	78	—	—	130	—	152	—	141
Percentage No. of *employés* (adult males)	—	—	4	—	—	3	—	—	—	3
Wool	—	—	81	—	—	152	—	171	—	168
No.	—	—	5	—	—	6	—	—	—	3
Building	—	—	70	—	—	173	—	173	—	148
No.	—	—	8	—	—	3	—	—	—	16
Mining	—	—	104	121	199	155	—	183	—	165
No.	—	—	15	—	—	34	—	—	—	33
Iron	—	—	81	—	—	186	—	184	—	181
No.	—	—	16	—	—	6	—	—	—	17
Printers	—	—	83	—	—	173	—	185	—	182
No.	—	—	1	—	—	2	—	—	—	2
Agriculture	54	57	59	69	103	103	99	—	100	—
No.	—	—	51	—	—	46	—	—	36	—
Weighted average	—	—	72	—	—	133	—	—	—	154
The same reduced so that 100 represents average wage in 1896	—	—	44	—	—	87	—	—	—	100
The same when agriculture is excluded	—	—	51	—	—	93	—	—	—	100

II. *Prices.*—Using the retail prices computed month by month in the 'Revue du Travail' issued by the Belgian Labour Office, and weighting the annual averages by weights obtained from the 'Budgets Ouvriers' collected in 1891, a list of index-numbers is drawn up from 1896. This is supplemented by the retail prices of a large grocery business selling all commodities of general use in 565 shops in industrial districts. The list so obtained for twenty years agrees very closely with the index-number of wholesale prices compiled by Professor H. Denis.

[1] Published in the *Statistical Journal*, September 1904.

TABLE II.—*Index-Numbers.*

Years	Wholesale Prices. Prof. H. Denis's Numbers (28 Articles, Export Statistics). Average Prices, 1867–1877=100	The same Average Prices, 1902=100	Retail Prices, Average Prices, 1902=100	Years	Wholesale Prices. Prof. H. Denis's Numbers (28 Articles, Export Statistics). Average Prices, 1867–1877=100	The same Average Prices, 1902=100	Retail Prices, Average Prices, 1902=100
1880	97	156	110	1892	66·5	104	105
1881	95	153	109	1893	64·4	101	106
1882	82	133	122	1894	59	93	102
1883	85	134	108	1895	61·5	96	96
1884	80	129	110	1896	61	95	95
1885	77	124	99	1897	56	88	99
1886	75	121	99	1898	58·5	79	98
1887	74	119	98	1899	61·8	97	96
1888	75	118	104	1900	63·4	99	98
1889	70	112	109	1901	63·1	99	98
1890	70	110	102	1902	64	100	100
1891	69·9	109	106				

III. *Real Wages.*—With the help of the price index-numbers the real wages of coal miners and iron workers are estimated.

TABLE III.—*Real Wages in Selected Trades in Belgium,* 1880–1902.

Years	Coal Miners [1]		Ironworkers (of John Cockerill Co.) [2]		Zincworkers (Vieille-Montagne Co.) [3]		Wool Trade (Verviers) [4]		Linen Trade (Liège) [5]	
	Average Nominal Wage [1]	Average Real Wage	Nominal Wage	Real Wage	Nominal Wage	Real Wage	Nominal Wage	Real Wage	Nominal Wage	Real Wage
	1902=100									
1880	77	70	—	—	93	84	—	—	—	—
1881	78	71	86	79	92	84	—	—	—	—
1882	80	65	84	69	94	77	—	—	—	—
1883	84	78	86	80	93	86	—	—	—	—
1884	77	76	83	75	95	86	—	—	—	—
1885	68	69	74	75	93	94	—	—	—	—
1886	65	66	75	76	93	94	—	—	93	94
1887	68	69	84	85	89	91	—	—	94	96
1888	72	69	86	83	91	87	—	—	89	85
1889	78	71	85	78	94	86	—	—	89	82
1890	93	91	93	91	90	88	—	—	92	90
1891	91	86	88	83	92	87	—	—	94	89
1892	80	76	90	86	95	90	—	—	92	88
1893	74	70	88	83	94	89	—	—	94	89
1894	79	77	85	83	96	94	94	92	95	93
1895	79	82	92	96	93	97	91	95	97	101
1896	82	86	89	94	92	97	90	95	99	104
1897	82	83	97	98	93	94	93	94	91	92
1898	92	94	97	99	89	91	85	86	98	100
1899	97	101	101	105	93	97	93	97	98	102
1900	118	120	105	107	94	96	91	93	104	106
1901	106	108	114	116	102	104	101	103	96	98
1902	100	100	100	100	100	100	100	100	100	100

[1] From 102,000 to 134,000 working men. [2] From 8,000 to 10,000 working men.
[3] About 1,300 men. [4] From 1,700 to 1,800 men. [5] From 1,000 to 1,200 men.

2. *The Development of Towns.* *By* T. C. Horsfall.

There is a great and complex interaction between a house, its surroundings, and its occupants. If homes are to be made more wholesome, all these three factors must be improved. Our schools must give better physical, mental, and moral training for life, and their influence must be extended by continuation classes. Houses must be put into, and maintained in, good order by a system of continuous inspection. In new districts houses must have pleasant surroundings, the air must be kept as free from smoke as possible, and the dwellings of persons of different social classes must be intermixed. While the building of tall tenement houses must be prevented, the 'one-family house' should cease to be the predominant type of workman's house in and quite near to large towns. The growth of towns should be controlled by extension plans, and building districts should be created—some reserved for manufactories, and others for dwellings. In the districts more remote from the centre houses should not be allowed to have as many storeys, and sites to have as large a proportion covered with buildings, as are allowed in districts nearer the centre of the town. Town councils should have the power to buy and hold land for general purposes, to rate land on its selling value, and to levy rates on increase of value when property is sold. The incorporation of surrounding districts by large towns should be made much easier. Tramlines ought to be made by town councils, but not till much land has been bought and a town extension plan prepared. Town councils ought to be strengthened by the employment of paid mayors and chairmen of committees, who ought to be appointed for long periods.

The most important of all the measures which can be taken at present for the improvement of housing are the improvement of town councils and the giving of a large amount of representation on education committees to teachers.

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3. *The Town Housing Question.* *By* Mrs. Fisher.

The fundamental difficulty of the question is the growth of town populations, which have been housed without any regard to hygienic conditions.

There are two main aspects of the problem: (1) the sanitary aspect, *i.e.*, the existence of slums and insanitary areas; and (2) the house famine. This, again, is of two kinds: first, and more rarely, a house famine due to special circumstances, *e.g.*, when the sudden growth of an industry causes an abnormal increase of population; second, a constant difficulty as to the supply of cheap houses. Increased cost of building has not checked the growth of superior house accommodation, but has interfered with the production of cheap houses, while improvements remove the old inexpensive cottages. Hence there is great pressure on those which still exist.

How have local authorities attempted to cope with these difficulties?

1. In the case of insanitary areas they have used Part I. of the Housing Act; in the case of small groups of bad houses improvements have been effected by Part II. and by the Public Health Act.

2. The preventive and regulative work of the sanitary authorities has done much, and might do more, to improve bad conditions and to stimulate healthy effort.

3. Lastly, there have been attempts to deal with the house famine by means of municipal house building and owning. There are several different policies with regard to this.

(*a*) The Liverpool policy of cheap tenement houses on central sites, the object of which is to rehouse the very poorest classes who now occupy court houses. The results are interesting, and there are many arguments for and against it.

Various devices have been attempted in order to secure the occupation of municipal houses by the really poor.

(*b*) Some advocate the plan of building ordinary houses or tenements in large number in order that municipal competition may lower the level of rents. The results of this are slight.

(*c*) Recently attempts have been made to develop suburban estates. This seems hopeful, but there are many difficulties, especially as to providing for the very poor on such estates.

The main task of house building must be left to private enterprise; the duty of local authorities is to urge private enterprise to do the very best that can be done. There are two main ways of bringing this about: (1) By wise building by-laws properly enforced; (2) by thorough administration of the sanitary laws. These two duties are at present very imperfectly performed. The urgent necessity of guarding suburbs and new districts is not yet realised.

Local authorities have experienced great difficulties, especially financial difficulties, as to their building schemes, but recent developments seem more hopeful. Local authorities ought (1) to make experiments, lead, and suggest (examples, Sheffield and Camberwell); (2) in cases of monopoly create competition; (3) where necessary deal with classes which cannot be left to private enterprise, but great caution is essential to the success of such plans.

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4. *The Increase of Suburban Populations.* *By* Sidney Low, *B.A.*

1. The transfer of population from rural to urban areas. A widely diffused tendency; noticeable not merely in Great Britain, but in Continental countries, and even in America and Australia.

2. Illustrations of this movement during recent years in England. Declining and increasing centres of population.

3. The movement, however, is not, as often represented, a mere migration from the country to the towns, but rather from the country to those spreading suburban districts which are partly urban and partly rural. The central areas of the towns, so far from increasing, are themselves stationary or declining. The four largest cities in England have advanced at a less rapid rate than the country generally. Taking London as a whole, there is a positive decrease in several of the districts which make up the 'Inner Ring,' and very little progress in others. On the other hand, there is enormous increase in the purely suburban agglomerations, such as Willesden, Walthamstow, and East Ham. The further we get from the centre of the town, so long as we do not pass beyond a distance accessible by cheap and rapid means of locomotion, the more marked is the expansion.

4. A consideration of this movement tends to mitigate the anxiety with which the migration from the rural districts is often regarded. No doubt the congestion of enormous masses in great cities is detrimental to health and attended by social evils of various kinds. It is often assumed that the stamina of a nation cannot be maintained unless a considerable proportion of its inhabitants live under rural conditions. But the suburb-dweller is free from many of the depressing and unwholesome influences which affect the townsman, and may enjoy the advantages of fresh air, facilities for exercise, and contact with Nature.

5. It is, however, necessary that the suburbs should be governed with as much vigilance and intelligent care as the great towns. At present large populations planted just outside the administrative ring-fence of the county or municipal borough are under inadequate supervision. To find a proper system of suburban government is one of the great social and political problems of the immediate future.

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5. *The Relation between Population and Area in India.* By J. A. BAINES, *C.S.I.*

The term 'density' may be applied to population in a sense merely numerical, or it may be taken to involve the economical consideration of relation to the means of subsistence. Used in the latter sense, with reference to a population producing the food it consumes, the determining factor is practically the fertility of the local resources. India comes under this head. Its population is mainly vegetarian, and the greatly predominating occupation is agriculture. In analysing the distribution of its population, therefore, the first consideration is the relative fertility of the various tracts, and, using the geographical divisions of the country as the base and remembering that tropical conditions prevail, the essential feature to be taken into account is the rainfall. Speaking generally, the concentration of population tends to vary directly as the rainfall, and inversely as its seasonal variability. There are several important instances in which this tendency is not apparent, but here it is kept in abeyance by special circumstances, such as unhealthy climate, political disturbances, or paucity of cultivable land on the one hand, and on the other by exceptional facilities for supplementing the rainfall by artificial irrigation.

There are few countries of any considerable size so uniform in the distribution of their population that the figure of their average density serves any purpose but that of the very broadest comparison, and its chief use in statistics is as a screen on which to illustrate its component variations. In India, with its unusual range of climatic and geographical variety, the average is peculiarly meaningless, and, compounded as it is largely from its two extremes, the density it implies actually prevails over but a comparatively small proportion of the area which contributes to it. The urban element in the population, again, enters but to a trifling extent into the calculation, as is only to be expected in a country so markedly agricultural in its pursuits and so largely self-supporting. As a rule, the most densely peopled tracts, except just round the large industrial seaports, are remarkable for the paucity of their urban aggregates beyond the size of the ordinary local market town. There are, on the other hand, parts of the country, especially in Native States, where a comparatively large town is found in the midst of a very thinly populated neighbourhood, to which it serves as a centre of commerce. The political and military considerations which used to determine the situation and prospects of an important town are now superseded almost everywhere by those connected with transport and manufacture. Except, however, along the coast and trunk lines of railway, the smaller urban centres prosper and wane with the fortunes of the surrounding peasantry.

The nature and extent of the shifting of the distribution of population of late years are subjects upon which the recent famines have made it difficult to reach satisfactory conclusions, nor were the exceptionally favourable circumstances of the preceding decennial period much more instructive. At best the rate of growth in the long-settled tracts does not appear to be other than moderate compared with that prevailing elsewhere, but the evidence of a state approaching congestion is not altogether convincing. Between 1881 and 1891 the most thickly peopled tracts showed a rate of increase very much below that of those with a more scattered population; but it is not improbable that in the latter the later census was far more accurately taken, so that much of the growth must be discounted accordingly. On the other hand, during the last decennium, the denser tracts showed, on the whole, a higher rate than the rest; but here, again, allowance must be made for the fortunate immunity from famine enjoyed by the former, as also for a certain multiplication of the means of subsistence which has characterised some of them.

On the whole, it appears certain that under present conditions any increase in population that occurs will fall directly upon the land, and in most parts of the country the means exist for meeting that pressure, at all events for some considerable time. Cultivable land not yet taken up is found in most provinces and States. In some comparatively remote regions this area is large and continuous,

and is now being placed within reach of immigrants by the extension of railways. Elsewhere the sinking of wells has intensified the cultivation, and the introduction of additional water supply by means of canals has rendered large areas productive which were before sterile. Congestion may be thus staved off for a generation, but must come, as the line of increase remains the same. There are, however, signs of the beginning of a process of diversion from agriculture to other industries. The urban population has recently shown a tendency to increase at a slightly higher rate than the rural, and though in the famine-stricken tracts this may be in part attributed to the traditional tendency of the field labourer to wander towards the doles and labour market of the nearest town, the growth of the seaports and manufacturing centres testifies to a real movement away from the fields. Whether the movement be permanent or, as in many cases it is known to be, merely seasonal, there is no doubt as to the increased advantage which is being taken of the openings afforded by the development of new undertakings within the last twenty years or even less, and the villager earns away from home more than the subsistence he used to himself produce there. The further step of emigration for employment out of India and its immediate neighbours is an outlet which also shows signs of expansion, but, like the migration to the plantations or factories, it is a matter of sentiment and custom, and, once acclimatised, often leads to a regular flow out and back. That the returned emigrant's savings are ultimately invested in the purchase of land in his birthplace is a matter that will have to be taken into account by the next generation.

6. *Investigations on the Nutrition of Man.* *By* Professor ATWATER.
See p. 758.

WEDNESDAY, AUGUST 24.

The following Papers were read :—

1. *The Modification of the Income-tax.*
By W. G. S. ADAMS.

The income-tax has become not merely permanent, but the centre round which our system of taxation is grouped. The case to be considered is not, however, that of radical reform, but of modification. The breaking-up of the income-tax into an income and a property tax is improbable; but the present income-tax is capable of considerable modification along the lines of development which it has followed.

Three questions are to be considered. First, the degressive scale should be extended and the graduation made 'smooth' instead of 'jolting.' A simple system of degression affecting incomes up to 1,000*l.* may be constructed. It should also be considered whether differential rates—such as Pitt and Gladstone had recourse to—should not be introduced, applying to (1) incomes below 250*l.* and (2) incomes above 1,000*l.*

Second, the normal level of the income-tax is too high. The income-tax must be adjusted in relation to modifications required alike in the Succession Duties and in our system of indirect taxation. Graduation through the medium of indirect taxation can be economically extended further than at present. Necessaries must be exempted to a larger extent, and articles of luxury taxed. The British system has been falling away from this standpoint.

Third, the income-tax should be extended downwards to all incomes over 120*l.* This is conditional on a reduction of the normal rate and on modifications of our system of indirect taxation. The wider extension of the tax through the body of the political electorate is of great importance. The position of the industrial

classes will not be affected adversely, but contrariwise, by the lines of change proposed.

Income		Percentage of Income	Amount	Present Amount Taxed	Percentage of Income
£			£ s.	£	
250	pays on	25	62 10	90	36
300	,,	30	90 0	140	46·6
350	,,	35	122 10	190	54·28
400	,,	40	160 0	240	60
450	,,	45	202 10	300	66·6
500	,,	50	250 0	350	70
550	,,	55	302 10	430	78·18
600	,,	60	360 0	480	80
650	,,	65	422 10	580	89·2
700	,,	70	490 0	630	90
750	,,	75	562 10	750	100
800	,,	80	640 0	800	100
850	,,	85	722 10	850	100
900	,,	90	810 0	900	100
950	,,	95	902 10	950	100
1,000	,,	100	1,000 0	1,000	100

2. *A proposed Substitute for the Sugar-tax.* By BARNARD ELLINGER.

The enormous growth of national expenditure during recent years has necessitated the reimposition of the import duty on sugar. The sugar-tax, however, is open to two important objections:—

1. It is a tax on an important article of food used by the very poor, and it is a tax which falls on the consumers in inverse ratio to their ability to bear it.
2. It is a tax on raw material, sugar being largely used in the manufacture of jams, confectionery, biscuits, mineral waters, &c.

The growth of expenditure has been sanctioned by the working class, who hold the power through their votes; and as a large part of this class are in enjoyment of comfortable incomes—the family as a unit often receiving a considerable income—it is both just and politic that they should share the burden imposed by the policy for which they have voted. The income-tax does not touch them; the tax on sugar does, but is open to the objections stated before.

Is it possible to find a tax which, while not open to these objections, would touch the pocket of the well-to-do lower middle class and artisan class?

An import and excise duty on meat would possibly meet the case.

Both import and excise duty would be charged on weight of dead meat, allowance being made in the case of home-slaughtered meat for offal, horns, hide, &c.

The excise duty would be collected through the medium of municipal or State slaughter-houses, private slaughter-houses being abolished. An excise duty has existed for many years in Holland, and works well.

The tax, being charged on the weight of dead meat, would be regulated by the butcher to a nicety according to the abilities of his various customers to bear the same.

Meat pieces sometimes bought by the very poor would probably escape the tax altogether, being in the nature of a by-product.

A tax of 3*s.* 6*d.* per cwt. would probably, while raising the price of meat by ½*d.* per lb., bring in a revenue from imported meat and cattle slaughtered at port of 3,700,000*l.*; and basing the figures of home-raised meat on the estimate of the

late Minister of Agriculture, Mr. Hanbury, the excise duty would bring in 8,600,000*l.*, *i.e.*, a total of 12,300,000*l.*

The figure, however, here used for home-raised cattle is probably exaggerated, and on an estimate based on the figures of the Select Committee of 1892 on the marking of foreign meat, and bringing these figures up to date, the excise duty would yield 4,500,000*l.*, or a total revenue of 8,200,000*l.*, *i.e.*, considerably more than the sugar-tax now yields.

The erection of public slaughter-houses is in itself desirable, and has been found to act well in Germany, even communities of 2,000 to 3,000 inhabitants having their own slaughter-house, smaller villages joining together in a common slaughter-house.

The tax is only advocated as a substitute for, and not as an addition to, the sugar-tax. At present the question probably lies outside the range of practical politics; but if the country ultimately decides to retain its present fiscal system, and finds itself still face to face with the problem of finding the best means of raising revenue to meet its enhanced expenditure, the suggestion contained in this paper may be deemed worthy of attention.

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3. *Some Features of the Labour Question in America.* *By* C. J. Hamilton.

'Within two years there will be the greatest conflict between organised labour and organised capital that the U.S.A. has yet seen. This prophecy, made by President Hadley last autumn, is in process of verification. It may be of interest to examine briefly some chief points in the situation. The immediate cause of the conflict is the general depression of trade, in consequence of which employers are reducing wages and dismissing hands. The unions, which have probably doubled their numbers since 1900, are opposing reduction and seeking shorter hours.

The true ground of the struggle is, however, the question of union recognition and the union shop. The discussion of the situation requires reference to :—

I. Some general considerations.

- *a.* Industrial conditions in U.S.A. are very various, differing as widely as the Lancashire of 1845 and of to-day.
- *b.* The working population comprises members of many nationalities, rapidly Americanised, but retaining a variety of foreign traditions.
- *c.* The negro problem is often acute, and will become more so.
- *d.* The industrial laws of the several States vary widely. They are in most cases far behind England and Germany in respect of factory laws, workmen's compensation, &c.

II. Union organisation.

a. Leadership.

Often characterised by

- i. Absence of a prolonged training.
- ii. Irish nationality.
- iii. Frequent resignation to undertake employing functions.
- iv. Evolution of the labour boss.

b. Following.

Shares the English characteristic of being generally impatient of slow development, and careless of properly exercising the functions of a democracy.

Their aim is becoming, increasingly, social equality rather than purely industrial amelioration.

III. Methods.

a. Limitation of output.
The commonest instinct of labour, which believes implicitly in the lump of labour fallacy.

b. Opposition to machinery.
Less common in America than in England.

c. The boycott.
The chief union instrument for securing their main object, *i.e.*, the union shop.

Consideration seems to show that the union shop is the end to be desired, but it must come not by coercion of employer, nor of *employé*, but by establishing the union's claim to be necessary to the worker, and not injurious to the employer or the public. The boycott takes various forms :—

a. The union label, an American device, said to be 'the strongest weapon of organised labour.'

b. Regular publication of fair lists and activity on the part of boycott agitators.

c. Generally assumes a violent form in the presence of actual hostilities.

While the creation of an *esprit de corps* and of a strong public opinion is legitimate, and necessarily implies some application of boycott principle, its excessive development is tyrannical and suicidal.

To meet the growing powers of organised labour, capital is rapidly associating in offensive and defensive alliances, irrespective of trade boundaries. Their methods appear similar to those of the unions, with the exception of a constant resort to the legal injunction. The struggle is thus becoming exceedingly bitter, and the outcome is at present in the balance.

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4. *The Employment of the Graduate. By* H. A. Roberts, *M.A.*

(i.) Problem to be solved by a modern British university; its complexity often overlooked. Need for continuous development. Influence on development of the market for employment. Growing importance of this influence since 1880. Graduate employment a faithful reflexion of national progress. Consequent diversification of careers the characteristic of the last twenty years.

(ii.) Sketch of graduate employment from 1870 to the present day. Till 1870 employment confined to 'the learned professions.' High percentage of graduates described as 'of no profession.' 1870–1880, years of tentative expansion. 1880–1895, growing diversity of employment; rise of new professions; employment in research, travelling, administration. Elimination of the class described as 'of no profession.' Tendency to 'practical' careers; business and the law. General tendency obscured in the early 'eighties by temporary increase of employment in education; reasons for this increase, and its bearing on the supply of teachers at the present moment; increase not completely explained by theory that men 'drifted into school-mastering.' The last decade. Diversity of careers remarkable; versatility of the graduate. Some careers of the present day.

(iii.) Questions of the moment.

Education as a career; demand and supply. Research. The co-operation of science and industry; progress already made; some difficulties; technical education and scientific training; the aspects of specialisation; need for organisation. Employment of graduates in business; never yet tried on a sufficient scale; the experiment still recent in America; the desirable training; degrees in economic science; degrees only a partial test of business efficiency; necessity for closer contact of universities and business men; suggestions; initial cost of graduate labour.

SECTION G.—ENGINEERING.

PRESIDENT OF THE SECTION—Hon. C. A. PARSONS, M.A., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

ON this occasion I propose to devote my remarks to the subject of invention.

It is a subject of considerable importance, not only to engineers but also to men of science and the public generally.

I also propose to treat invention in its wider sense, and to include under the word discoveries in physics, mechanics, chemistry, and geology.

Invention throughout the Middle Ages was held in little esteem. In most dictionaries it receives scant reference except as applied to poetry, painting, and sculpture.

Shakespeare and Dryden describe invention as a kind of muse or inspiration in relation to the arts, and when taken in its general sense to be associated with deceit, as 'Return with an invention, and clap upon you two or three plausible lies.'

As to the opposition and hostility to scientific research, discovery, and mechanical invention in the past, and until comparatively recent times, there can be no question, in some cases the opposition actually amounting to persecution and cruelty.

The change in public opinion has been gradual. The great inventions of the last century in science and the arts have resulted in a large increase of knowledge and the powers of man to harness the forces of Nature. These great inventions have proved without question that the inventors in the past have, in the widest sense, been among the greatest benefactors of the human race. Yet the lot of the inventor until recent years has been exceptionally trying, and even in our time I scarcely think that anyone would venture to describe it as altogether a happy one. The hostility and opposition which the inventor suffered in the Middle Ages have certainly been removed, but he still labours under serious disability in many respects under law as compared with other sections of the community. The change of public feeling in favour of discovery and invention has progressed with rapidity during the last century. Not only have private individuals devoted more time and money to the work, but societies, institutions, colleges, municipalities, and Governments have founded many research laboratories, and in some instances have provided large endowments. These measures have increased the number of persons trained to scientific methods, and also provided greatly improved facilities for research; but perhaps one of the most important results to engineers has been the direct and indirect influence of the more general application of scientific methods to engineering.

Sir Frederick Bramwell, in his Presidential Address to this Association in 1888, emphasised the interdependence of the scientist and the civil engineer, and described how the work of the latter has been largely based on the discoveries of the

former; while the work of the engineer often provides data and adds a stimulus to the researches of the scientist. And I think his remarks might be further appropriately extended by adding that since the scientist, the engineer, the chemist, the metallurgist, the geologist, all seek to unravel and to compass the secrets of Nature, they are all to a great extent interdependent on each other.

But though research laboratories are the chief centres of scientific invention, and colleges, institutions, and schools train the mind to scientific methods of attack, yet in mechanical, civil, and electrical engineering the chief work of practical investigation has been carried on by individual engineers, or by firms, syndicates, and companies. These not only have adapted discoveries made by scientists to commercial uses, but also in many instances have themselves made such discoveries or inventions.

To return to the subject, let us for a moment consider in what invention really consists, and let us dismiss from our minds the very common conception which is given in dictionaries and encyclopædias that invention is a happy thought occurring to an inventive mind. Such a conception would give us an entirely erroneous idea of the formation of the great steps in advance in science and engineering that have been made during the last century; and, further, it would lead us to forget the fact that almost all important inventions have been the result of long training and laborious research and long-continued labour. Generally, what is usually called an invention is the work of many individuals, each one adding something to the work of his predecessors, each one suggesting something to overcome some difficulty, trying many things, testing them when possible, rejecting the failures, retaining the best, and by a process of gradual selection arriving at the most perfect method of accomplishing the end in view.

This is the usual process by which inventions are made.

Then after the invention, which we will suppose is the successful attempt to unravel some secret of Nature, or some mechanical or other problem, there follows in many cases the perfecting of the invention for general use, the realisation of the advance or its introduction commercially; this after-work often involves as great difficulties and requires for its accomplishment as great a measure of skill as the invention itself, of which it may be considered in many cases as forming a part.

If the invention, as is often the case, competes with or is intended to supersede some older method, then there is a struggle for existence between the two. This state of things has been well described by Mr. Fletcher Moulton. The new invention, like a young sapling in a dense forest, struggles to grow up to maturity, but the dense shade of the older and higher trees robs it of the necessary light. If it could only once grow as tall as the rest all would be easy, it would then get its fair share of light and sunshine. Thus it often occurs in the history of inventions that the surroundings are not favourable when the first attack is made, and that subsequently it is repeated by different persons, and finally under different circumstances it may eventually succeed and become established.

We may take in illustration almost any of the great inventions of undoubted utility of which we happen to have the full history—for instance, some of the great scientific discoveries, or some of the great mechanical inventions, such as the steam-engine, the gas-engine, the steamship, the locomotive, the motor-car, or some of the great chemical or metallurgical discoveries. Are not most, if not all, of these the result of the long-continued labour of many persons, and has not the financial side been, in most cases, a very important factor in securing success?

The history of the steam-engine might be selected, but I prefer on this occasion to take the internal-combustion engine, for two reasons—firstly, because its history is a typical one; and secondly, because we are to hear a paper by that able exponent and great inventor in the domain of the gas-engine, Mr. Dugald Clerk, describing not only the history, but the engine in its present state of development and perfection, an engine which is able to convert the greatest percentage of heat units in the fuel into mechanical work, excepting only, as far as we at present know, the voltaic battery and living organisms.

The first true internal-combustion engine was undoubtedly the cannon, and the use in it of combustible powder for giving energy to the shot is strictly analogous to the use of the explosive mixture of gas or oil and air as at present in use in all internal-combustion engines; thus the first internal-combustion engine depended on the combination of a chemical discovery and a mechanical invention, the invention of gunpowder and the invention of the cannon.

In 1680 Huygens proposed to use gunpowder for obtaining motive power in an engine. Papin, in 1690, continued Huygens' experiments, but without success. These two inventors, instead of following the method of burning the powder under pressure, as in the cannon, adopted, in ignorance of thermodynamic laws, an erroneous course. They exploded a small quantity of gunpowder in a large vessel with escape valves, which after the explosion caused a partial vacuum to remain in the vessel. This partial vacuum was then used to actuate a piston or engine and perform useful work. Subsequently several other inventors worked on the same lines, but all of these failed on account of two causes which now are very evident to us. Firstly, gunpowder was then, as it still is, a very expensive form of fuel, in proportion to the energy liberated on explosion; secondly, the method of burning the powder to cause a vacuum involves the waste of nearly the whole of the available energy, whereas had it been burned under pressure, as in the cannon, a comparatively large percentage of the energy would have been converted into useful work. But even with this alteration, and however perfect the engine had been, the cost of explosives would have debarred its coming into use, except for very special purposes.

We come a century later to the first real gas-engine. Street, in 1794, proposed the use of vapour of turpentine in an engine on methods closely analogous to those successfully adopted in the Lenoir gas-engine of eighty years later, or thirty years ago. But Street's engine failed from crude and faulty construction. Brown, in 1823, tried Huygens' vacuum method, using fuel to expand air instead of gunpowder, but he also failed, probably on account of the wastefulness of the method.

Wright, in 1833, made a really good gas-engine, having many of the essential features of some of the gas-engines of the present day, such as separate gas and water pumps, and water-jacketed cylinder and piston.

Barnett, in 1839, further improved on Wright's design, and made the greatest advance of any worker in gas-engines. He added the fundamental improvements of compression of the explosive mixture before combustion, and he devised means of lighting the mixture under pressure, and his engine conformed closely to the present-day practice as regards fundamental details. No doubt Barnett's engine, so perfect in principle, deserved commercial success, but either his mechanical skill or his financial resources were inadequate to the task, and the character of the patents would seem to favour this conclusion, both as regards Barnett and other workers at this period. Up to 1850 the workers were few, but as time went on they gradually increased in numbers; attention had been attracted to the subject, and men with greater powers and resources appear to have taken the problem in hand. Among these numerous workers came Lenoir, in 1860, who, adopting the inferior type of non-compression engine, made it a commercial success by his superior mechanical skill and resources. Mr. Dugald Clerk tells us: 'The proposals of Brown (1823), Wright (1833), Barnett (1838), Bansanti and Matteucci (1857), show gradually increasing knowledge of detail and the difficulties to be overcome, all leading to the first practicable engine in 1866, the Lenoir.' This stage of the development being reached, the names of Siemens, Beaude Roches, Otto Simon, Dugald Clerk, Priestman, Daimler, Dowson, Mond, and others, appear as inventors who have worked at and added something to perfect the internal-combustion engine and its fuel, and who have helped to bring it to its present state of perfection.

In the history of great mechanical inventions there is perhaps no better example of the interdependence of the engineer, the physicist, and the chemist than is evinced in the perfecting of the gas-engine. The physicist and the chemist together determine the behaviour of the gaseous fuel, basing their theory on data

obtained from the experimental engines constructed by the mechanical engineer, who, guided by their theories, makes his designs and improvements; then, again, from the results of the improvements fresh data are collected and the theory further advanced, and so on till success is reached. But though I have spoken of the physicist, the chemist, and the engineer as separate persons, it more generally occurs that they are rolled into one, or at most two, individuals, and that it is indispensable that each worker should have some considerable knowledge of all the sciences involved to be able to act his part successfully.

Now let us ask, Could not this very valuable invention, the internal-combustion engine, have been introduced in a much shorter time by more favouring circumstances, by some more favourable arrangement of the patent laws, or by legislation to assist the worker attacking so difficult a problem? I think the answer is that a great deal might be done, and I will endeavour to indicate some changes and possible improvements.

The history of this invention brings before our minds two important considerations. Firstly, let us consider the patentable matter involved in the invention of the gas-engine, the utilisation for motive-power purposes of the then well-known properties of the explosive energy of gunpowder or of mixtures of gas and oil with air. Are not these obvious inferences to persons of a mechanical turn of mind and who had seen guns fired, or explosions in bottles containing spirits of turpentine when slightly heated and a light applied to the neck? Surely no fundamental patent could have been granted under the existing patent laws for so obvious an application of known forces. Consequently, patent protection was sought in comparative details, details in some cases essential to success which were evolved or invented in the process of working out the invention. In this extended field of operations a slight protection was in some instances obtained. But in answer to the question whether such protection was commensurate with the benefits received by the community at large, there can, I think, be only one reply. Generally, those who did most got nothing, some few received insufficient returns, and in very few cases indeed can the return be said to have been adequate. The second important consideration is that of the methods of procedure of the patentees, for it appears that very few of them had studied what had been suggested or done before by others before taking out their own patent. We are also struck by the number of really important advances that have been suggested and have failed to fructify, either from want of funds or other causes, to be forgotten for the time and to be re-invented later on by subsequent workers.

What a waste of time, expense, and disappointment would be avoided if we in England helped the patentee to find out easily what had been done previously, on the lines adopted by the United States and German Patent Offices, who advise the patentee after the receipt of his provisional specification of the chief anticipatory patents, dead or alive! And ought we in England to rest content to see our patentees awaiting the report of the United States and German Patent Offices on their foreign equivalent specifications before filing their English patent claims? Ought not our Patent Office to give more facilities and assistance to the patentee?

Before proceeding further to discuss some of the possible improvements for the encouragement and protection of research and invention, I ask you to further consider the position of the inventor—the man anxious to achieve success where others have hitherto failed. To be successful he must be something of an enthusiast; and usually he is a poor man, or a man of moderate means, and dependent on others for financial assistance. Generally the problem to be attacked involves a considerable expenditure of money; some problems require great expenditure before any return can thereby accrue, even under the most favourable circumstances. In the very few cases where the inventor has some means of his own they are generally insufficient to carry him through, and there have unfortunately been many who have lost everything in the attempt. In nearly all cases the inventor has to co-operate with capital: the capitalist may be a sleeping partner, or the capital may be held by a firm or syndicate, the inventor in such cases being a partner—a junior partner—or a member of the staff. The com-

bination may be successful and lasting, but unfortunately the best inventors are often bad men of business. The elements of the combination are often unstable, and the disturbing forces are many and active; especially is this so when the problem to be attacked is one of difficulty, necessitating various and successive schemes involving considerable expenditure, generally many times greater than that foreshadowed at the commencement of the undertaking. Under such circumstances, unless the capitalist or the senior partner or board be in entire sympathy with the inventor or exercise great forbearance, stimulated by the hope of ultimate success and adequate returns, the case becomes hopeless, disruption takes place, and the situation is abandoned. Further, in the majority of cases, after some substantial progress has been made it is found that under the existing patent laws insufficient protection can be secured, and the prospect of a reasonable return for the expenditure becomes doubtful. Under such circumstances the capitalist will generally refuse to proceed further unless the prospect of being first in the field may tempt him to continue.

Very many inventors, as I have said, avoid the expense of searching the patent records to see how far their problem has been attacked by others. In some cases the cost of a thorough search is very great indeed; sometimes it is greater than the cost of a trial attack on the problem. In the case of young and inexperienced inventors there sometimes exists a disinclination to enter on an expensive search; they prefer to spend their money on the attack itself. There are some, it is true, who have a foolish aversion to take steps to ascertain if others have been before them, and who prefer to remain in ignorance and trust to chance. It will, however, be said that the United States and German Patent Office reports ought to suffice to warn or protect the English patentee; but my own experience has been that such protection is not entirely satisfactory. There is, firstly, a considerable interval before such reports are received, and the life of a patent is short. Then, if the patent is upon an important subject, attracting general attention, the search is vigorous and sometimes overwrought, and the patent unjustly damaged or refused altogether. If, however, the patent is on some subject not attracting general attention, it receives too little attention and is granted without comment.

In some few instances it may be said that ignorance has been a positive advantage, and that if the patentee had realised how much of his patentable work was honeycombed by previous publications and patents, he would have lost heart and given up the task. It is, I think, a case of the exception proving the rule; and the patentee ought, as far as possible, in all cases to know his true position, and make his choice accordingly. The present patent law has some curious anomalies. Let us suppose some inventor has the good fortune to place the keystone in the arch of an invention, to add some finishing touch which makes the whole invention a complete success, and valuable. Then, success having been proved possible, others try to reap the results of his labour and good fortune, and, as often happens, it is discovered after laborious search that someone else first suggested the same keystone in some long-forgotten patent or obscure publication, but for some reason or other the public were none the better for his having done so. What does the law do? It says this is an anticipation, and instead of apportioning to all parties reasonable and equitable shares in the perfected invention, to which no one could object, it says that the patent is injured or perhaps rendered useless by the anticipation, and that its value to everyone concerned is thereby diminished or destroyed, as the case may be, and thrown open to the public. Up till a few years ago, any anticipations, however old, might be cited; but recently the law has been amended, and at present none rank as anticipations which are more than fifty years old.

The perfecting of inventions and their introduction into general use requires capital, as we have seen—sometimes a considerable amount, as in the introduction of the Bessemer process for steel, or the linotype system of printing—before any commercial success can be realised.

Capital having been found, the next difficulty is in the conservatism of persons and communities who are the buyers of the invention. There is always present

in their minds the risk of failure and its consequent loss and worry to themselves, and in the event of success the advantage, in their estimation, may not be sufficient to counterbalance the risk. In large departments and companies whose management is conducted by officials receiving fixed salaries, acting under non-technical supervision, there is a strong tendency among the officials to leave well alone, the organisation being such that the risk of failure, even though it be remote, more than counterbalances, in their estimation, the advantages that would result in the event of success. Next is the opposition of those who are financially interested in competing trades or older inventions; and if the invention is a labour-saving appliance, then the active opposition of the displaced labour is a serious, though generally only a temporary, barrier.

Fortunately, however, for the community, for research, and for invention, there is always to be found a considerable percentage of persons who, apart from the inventor, are able and willing to risk, and indeed to sacrifice, their personal interests in the cause of progress for the benefit of the community at large; and were it not for such persons the task of the introduction of most inventions would be an impossible one.

There are many problems of the highest importance in physics, engineering, chemistry, geology, and the arts, of which the investigation might probably prove of great benefit to the human race, and of which the probable monetary cost of the attack would be considerable, and of some very great indeed. Let us, then, inquire how the necessary funds could be raised. It is possible in the case of some of the more attractive problems that a group of rich philanthropists might be found, but in most cases it would be impossible to form a company on business lines, under the existing laws of this and other countries, as I shall endeavour to show.

In the case of many of the problems, no patents will give adequate protection; in some cases there is no subject-matter of novelty and importance involved. In other cases the probable duration of the investigation is so long that any initial patents would have expired before a commercial result was reached, and under either of these circumstances there would be no inducement to business men or financiers to undertake the risk.

As an illustration of my meaning I will take two investigations that have doubtless occurred to the minds of most of those present, though many others of greater or less importance might be cited. One is the thorough investigation of the problem of aerial navigation, with or without the assistance of flotation by gas. This problem could undoubtedly be successfully solved by an organised attack of skilled and properly trained engineers and the expenditure of a large sum of money. Assuming the problem solved, and commercially successful, it appears to be impossible under the existing patent laws to secure any adequate monopoly so as to justify the expectation of a reasonable return on the capital expended on the invention. For in view of the multitude of suggestions that have been made and the experiments that have been carried out, the practical solution of the problem would appear to rest on a judicious selection of old ideas by means of exhaustive experiments.

Another and perhaps more important investigation which has not, as yet, been attacked to any material extent is the exploration of the lower depths of the earth. At present the deepest shaft is, I believe, at the Cape, of a little over one mile in depth, and the deepest bore-hole is one made in Silesia, by the Austrian Government, of about the same depth. What would be found at greater depths is at present a matter for conjecture, founded on the dip and thicknesses of strata observed on or near the surface. Much money and many valuable lives have been devoted to exploration of the polar regions, but there can be no comparison between the scientific interest and the possible material results of such exploration and the one I have chosen for illustration of the inadequate protection afforded by law—namely, a great engineering attack on a problem of geology.

I would ask you to consider the commercial aspect of this engineering geological enterprise, as compared with exploration into new or unknown areas on the surface of the earth.

An exploring expedition into a new country has before it generally the

probability of the acquisition of territorial and mineral rights or possessions bringing material gain to the undertakers. The rights of such enterprises are well known, and capital can be obtained with or without national support, as the case may be. On the other hand, the explorer into the depths of the earth has no rights or monopolies beyond the mineral rights of the land he has purchased over his boring; further, it is improbable that he can obtain any patent of substantial value for his methods of boring to great depths. To succeed in the undertaking a great expenditure of money must be incurred, an expenditure far greater than that of an exploring expedition, and analogous to that of a military expedition or a small invading army, and to raise this sum the pioneers have practically no security to offer. For if they succeed in finding rich deposits of precious minerals in greater abundance, or succeed in making some geological discovery associated with deep borings, they gain no exclusive title to these under existing laws. Any other person or syndicate acting upon the experience gained could sink other shafts in other places or countries, and, benefiting by the experience gained by the pioneers, could probably carry out the work more advantageously, and thus depreciate the first undertaking or render it valueless, as has often occurred before.

Let us consider more closely some of the essential features of sinking a shaft to a great depth, for I think it will be seen that it presents no unsurmountable difficulties beyond those incidental to an enterprise of considerable magnitude involving the ordinary methods of procedure and the ordinary methods adopted by mining engineers. That there would be some departures from ordinary practice on account of the great depth it is true, but these are more of the character of detail. On the design of this boring I have consulted Mr. John Bell Simpson, the eminent authority on mining in the North of England. The shaft would be sunk in a locality to avoid as far as possible water-bearing strata and the necessity of pumping. It would be of a size usual in ordinary mines or coal-pits. The exact position of such shaft would require some consideration as to whether it should commence in the primary or secondary strata. It would be sunk in stages, each of about half a mile in depth, and at each stage there would be placed the hauling and other machinery, to be worked electrically, for dealing with each stage. The depth of each stage would be restricted to half a mile in order to avoid a disproportionate cost in the hauling machinery and the weight of rope, as well as increased cost in the cooling arrangements arising from excessive hydraulic pressures. At each second or third mile in depth there would be air-locks to prevent the air-pressure from becoming excessive owing to the weight of the superincumbent air, which at from two to three miles would reach about double the atmospheric pressure at the surface. A greater rise of pressure than this would be objectionable for two reasons—firstly, from the inconvenience to the workmen; secondly, from the rise of temperature due to the adiabatic compression of the circulating air for ventilating purposes. The air-pressure immediately above each air-lock would thus reach to about two atmospheres, and beneath to one atmosphere. In order to carry on the transfer of air through the air-locks for ventilating purposes pumps coupled to air-engines would be provided, the energy to work the pumps being obtained from electro-motors. To maintain the shaft at a reasonable temperature at the greater depth powerful means of carrying the heat to the surface would be provided.

The most suitable arrangement for cooling would probably consist of large steel pipes, an upcast and a downcast pipe, connected at the top and bottom of each half-mile section in a closed ring. This ring would be filled with brine, which by natural circulation would form a powerful carrier of heat; but the circulation, assisted by electrically driven centrifugal pumps, would be capable of carrying an enormous quantity of heat upwards to the surface. At each half-mile stage there would be a transfer of the heat from the ring below to the ring above by means of an apparatus similar in construction to a feed-water heater, or to a regenerator constructed of small steel tubes, through which the brine in the ring above would circulate, and around the outside the brine in the ring below could also circulate, the heat being transmitted through the metal of the tubes from brine ring to brine ring.

We have now presented to us two alternative arrangements for cooling. One arrangement would be to cool the brine to a very low temperature in the top ring at the mouth of the shaft by refrigerating machinery, so as to provide a sufficient gradation of temperature in the whole brine system, to ensure the necessary flow of heat upwards from brine ring to brine ring, and overcome all the resistances of heat-transfer, and so maintain the lowest ring at the temperature necessary for effectual cooling of the lowest section of the shaft. But a better arrangement would be to place powerful refrigerating machinery at certain of the lower stages, the function of this machinery being to extract heat from the ring below and deliver it to the ring above. This latter method would increase to a very great extent the heat-carrying power of the system, which in the first arrangement is limited by the freezing temperature of brine in the descending column and the highest temperature admissible in the ascending brine column. The amount of heat conducted inwards through the rock-wall and requiring to be absorbed and transferred to the surface depends on the temperature and conductibility of the strata. But there is no doubt that the methods I have indicated would be capable of maintaining a moderate temperature in the shaft to depths of twelve miles.

During the process of sinking at the greater depths the shaft bottom would require the application of a special cooling process in advance of the sinkers, similar to the Belgian freezing system of M. Poesche used for sinking through water-bearing strata and quicksands, and now in general use. It consists in driving a number of bore-holes in a circle outside the perimeter of the shaft to be sunk; through these bore-holes very cold brine is circulated, thus freezing the rocks and quicksands and the water therein, and when this process is completed the sinking of the shaft is easily accomplished.

In our case this process would be maintained not only on the shaft bottom, but also for some time on the newly-pierced shaft sides, until the surrounding rock had been cooled for some distance from the face.

As to the cost, rate of boring, and normal temperature of the rock, an approximate estimate has been made, based on the experience gained on the Rand, but including the extra costs for air-locks and cooling :—

	Cost £	Time in Years	Temperature of Rock
For 2 miles depth from the surface .	500,000	10	122° F.
,, 4 ,, ,, ,, ,, ,, .	1,100,000	25	152°
,, 6 ,, ,, ,, ,, ,, .	1,800,000	40	182°
,, 8 ,, ,, ,, ,, ,, .	2,700,000	55	212°
,, 10 ,, ,, ,, ,, ,, .	3,700,000	70	242°
,, 12 ,, ,, ,, ,, ,, .	5,000,000	85	272°

I hope I have succeeded in showing in the short time at our disposal that an exploration to great depths is not an impossible undertaking. But my main object in discussing the enterprise at some length has been to show that a pioneer company would not acquire any subsequent monopoly of similar works under the existing patent laws or the laws of any country.

In the scheme as I have described it, there appears to be nothing that could be patented; but let us suppose that some good patent could have been found that was absolutely essential to the success of the undertaking, it would certainly have expired before the pioneer company could have reaped any substantial return, and probably before the first enterprise had been completed. It follows therefore that at the present time there is no adequate protection, or indeed any protection at all, for the promoters of many great and important pioneer enterprises, some of which might prove of immense benefit to mankind.

Let us ask what change in the laws would place great pioneer research works on a sound financial basis. A Government grant, except for very special purposes, seems to be out of the question, seeing that the benefits to be derived are generally not confined to any one country. An extension of the life of patents, which is now from fourteen to sixteen years in different countries, would be

undoubtedly a step in the right direction. It would be of great benefit generally if some scale of duration of patents could be fixed internationally, the scale being fixed according to the subject-matter, the difficulty of the attack, and the past history of the subject, but more especially in view of the utility of the invention.

One of the chief objections raised by the Privy Council against the extension of patents in this country has rightly been that undue prolongation is unfair to the British public, seeing that abroad no prolongations are granted. Therefore, if the duration of patents for important matters is to be extended at home it must also be extended abroad. In other words, such prolongations, to be effective, should necessarily extend to other countries. They should be international, and concurrent in all the countries interested.

One possible solution of this difficult question would be to place such matters under the jurisdiction of a Central International Committee, who would have the apportionment of the life and privileges of patents and of the extension or curtailment of their duration, according to their handling by the owners. I would ask, Why has a patent a life of only fourteen to sixteen years, while copyright is for forty-two years? Why has a pioneer company making a railway under Act of Parliament generally rights for ever unless it abuses its privileges, or the requirements of the district necessitate the construction of competing lines, while a patent has in comparison a life of infinite shortness?

I might also cite gas companies, electrical supply companies, under Act of Parliament, or provisional orders of forty-two years' duration; and this reminds us of the fact that until the term of life for electric supply companies had been extended from twenty-one years to forty-two years by the bill of 1884, it was impossible to find capital for such undertakings.

Now, it may be urged that the grant of a patent is a different thing from the grant of power to a railway company, a gas or electric supply company. But the object of this Address has been to show that a patent, to be fair to the patentee, ought in many cases to be analogous to an Act of Parliament or a provisional order. Would it not place matters in a fairer position, especially in the case of expensive and lengthy researches, to grant to those who pledge themselves to spend a suitable and minimum sum within a stated period on the research a reasonable and fair monopoly, so that such person or syndicate might in the event of success be in the position to reap a reasonable return for their expenditure and risk?

Some such measure would unquestionably give an immense stimulus to research and invention by enabling capital to be raised and works started on commercial lines in fields of great promise at present almost untouched.

I pass over the disadvantages to the British inventor of the hostile patent tariffs of Continental nations and of the protective patent laws of some of the British dependencies, disadvantages greater than those imposed by protective tariffs on the ordinary British manufacturer.

There is, however, another aspect of the question to which I would briefly allude: it is the great benefits that the world at large has derived from the work of inventors in the past.

Think of the multitude and power of the great steam-engines and gas-engines that drive our factories, and pump the water out of our mines, and supply our cities with water, light, and power; of the great steamships scattered over the ocean and the locomotives on the railways.

Think of the billions of tons of steel that have been made by the Bessemer, Siemens-Martin, and Thomas Gilchrist processes, and of the great superiority and less cost of the material over the puddled iron which it superseded.

Think of the vast work performed by the electric telegraphs and telephones; and we must not fail to include the great chemical and metallurgical processes carried on all over the world, besides the countless other inventions and labour-saving appliances.

Can we form any idea of the commercial value of all these gigantic tools that past inventors have left as a heritage to the human race, and can we venture to place any order of magnitude on so vast a sum?

If we take as our unit of value the whole of the money spent on all inventions, both successful and unsuccessful, I think we shall be much below the mark if we assume that the value of the benefits have on the average exceeded by ten-thousandfold the money spent on making and introducing the inventions.

If this is so, let us see what it means. It means that for every unit of capital spent by the inventors and their friends on invention they have in some cases received nothing back. In some cases they have just got their capital back, in some cases two or threefold, occasionally tenfold, very rarely a hundredfold. Whereas the world at large has received a present of ten-thousandfold greater value than all the money spent and misspent by the small band of past inventors.

In conclusion, let us hope that the inventor will in the future receive more encouragement and support, that the patent laws will be further modified and extended, that the people at large will consider these matters more closely and recognise that they are of first importance to their progress and welfare, and that in the future it may be easier, nay in some cases possible, to carry on many great researches into the secrets of Nature.

Mrs. HERTHA AYRTON delivered a Lecture on 'The Origin of Sand Ripples.'

FRIDAY, AUGUST 19.

The following Papers were read:—

1. *Flame Temperatures in Internal Combustion.*[1] *By* DUGALD CLERK.

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2. *On the Specific Heats of Gases at High Temperatures.* *By* Professor H. B. DIXON, *F.R.S.*

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3. *Exhaust Gas Calorimetry.*[2] *By* Professor B. HOPKINSON, *M.A.*

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4. *The Effect of Receiver Drop in a Compound Engine.*[3] *By* J. W. HAYWARD, *M.Sc.*

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5. *Superheated Steam: Wire-drawing and other Experiments.* *By* A. H. PEAKE, *B.A.*

This paper gave an account of experimental investigations carried out with the object of determining the specific heat of superheated steam.

The first method dealt with was the one known as wire-drawing, or throttling. Dry saturated steam was allowed to expand without doing external work by causing it to pass through a small orifice, and the resulting changes in pressure and temperature were noted. This experiment was repeated for a number of initial pressures, and with each initial pressure the amount of wire-drawing was varied, so as to give a large number of points connecting temperature and pressure of the wire-drawn steam.

A diagram was shown in which these points were plotted on squared

[1] Published in the *Electrical Engineer*, September 2, 1904.
[2] Published in *Engineering*, August 26, 1904.
[3] Published in the *Engineer*, August 26, 1904.

paper, with temperatures as ordinates and pressures as abscissæ, and lines or curves were drawn through each set of points for which the initial pressure was the same. These curves, which are very nearly straight lines, are constant total heat curves; that is, the total heat in 1lb. of steam is the same for all points lying on any one curve, and the value of the total heat can be obtained from Regnault's tables for the total heat of saturated steam by noting the point on the saturation curve where the constant total heat curve cuts it.

Hence from this diagram, if Regnault's tables were quite accurate, the specific heat of superheated steam over the range of temperature and pressure covered by these experiments—212° Fahr. to 390° Fahr., and from atmospheric pressure up to 200 lb. per square inch—could be calculated.

Unfortunately, Regnault's tables are not sufficiently accurate for this purpose, since slight errors in the values of the total heat cause large variations in the calculated value of the specific heat.

The main interest, therefore, as far as the wire-drawing experiments are concerned, is in the results shown in the diagram referred to, which shows at a glance the whole of the experimentally obtained data.

The paper contained diagrams illustrating the apparatus used, and also tables, &c., showing the conclusions that would follow if Regnault's tables could be regarded as reliable enough to base such calculations upon.

The description of the apparatus, the method of procedure, the precautions taken to avoid errors and to secure perfectly dry steam before expansion, cannot be dealt with in a short abstract.

Experiments by a direct method have also been carried out. In these heat was supplied by passing a current of electricity through German-silver coils, over which the steam passed. The flow of steam and the electric energy supplied were kept as constant as possible until a steady condition was reached, and then the connection was obtained between rise of temperature, quantity of steam per minute, and watts supplied.

Radiation was very largely avoided by causing the steam to pass through an arrangement of concentric passages. The loss in this way which remained was estimated by experiment.

The experiments were carried out with steam at various pressures and for different amounts of temperature rise, but the results are not sufficiently accurate to enable any conclusions to be drawn as to variations of specific heat with temperature or pressure. In all cases the steam before heating was at saturation temperature.

The value obtained for the specific heat at constant pressure varied between ·36 and ·45, the mean of ten experiments giving the value ·41.

MONDAY, AUGUST 22.

The following Papers were read:—

1. *Electricity from Water-Power.*[1] *By* A. A. Campbell Swinton.

Though, probably, the earliest example of the production of electricity by means of water-power on a practical scale and its transmission to a distance was the installation put up at Cragside, Northumberland, by the late Lord Armstrong, in the year 1882, the great development of such installations has, until recently, taken place almost exclusively abroad. A few thousand horse-power will probably cover the whole of the plants of this character at present running in Great Britain; whereas, as was shown by a table in the paper, the aggregate horse-power of all the hydraulic electricity installations in the world amounts to at least one and a half million horse-power, and probably reaches two million horse-power.

By the utilisation of this water-power the author calculates that some 11,720,000

[1] Published in the *Electrical Engineer*, August 26, 1904.

tons of coal are saved annually, which, at 10*s.* per ton, means a yearly saving of some 5,860,000*l.*

The electrical transmission of energy generated by water-power has reached a great development in America, the longest transmission being probably the 232 miles of line that connect the De Sabla power-house with the town of Sausalito, in California. The author gave particulars of several other American and Continental installations of large size delivering energy over great distances.

The only large electro-hydraulic plant at present in operation in this country is the 7,000 horse-power installation of the British Aluminium Company at Foyers, which has been working since 1896. The same Company are, however, now developing a further installation on Loch Leven, whereby they expect to get 17,000 horse-power, the whole of which will be used for the production of aluminium.

Another large water-power scheme is at the present moment being developed in Wales by the North Wales Electric Power Company, whose first installation—which derives its power from Lake Llydaw—with a fall of 1,150 feet will give 8,200 horse-power.

The latest British scheme is that of the Scotch Water-Power Syndicate, who are developing a water-power obtainable from Loch Sloy, situated near Loch Lomond. The fall is 757 feet. The energy will be transmitted at 40,000 volts overhead for a distance of twenty-two miles to the industrial areas of the Vale of Leven and the Clyde, where it is calculated there will be 5,000 horse-power available for delivery.

The author calculates generally, with regard to water-power installations in this country, that interest on capital, depreciation, upkeep, and working expenses will amount to about 12 per cent. on the capital expenditure, so that for a water-power scheme to be economically sound the total capital involved must not exceed eight and a half times the annual price which can be got for the whole of the energy.

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2. *The Use of Electricity on the North-Eastern Railway and on Tyneside.*[1] *By* C. H. MERZ *and* W. McLELLAN.

The objects of this paper were (1) to describe the application of electricity to railway traction by the North-Eastern Railway Company as recently inaugurated; (2) to indicate the rapid progress which has been made in the uses of electricity in the Tyneside neighbourhood, resulting in the displacement of 50,000 horse-power of steam machinery; and (3) to discuss briefly the principles which govern the cheap generation and distribution of electricity for industrial purposes.

The Electrification of the North-Eastern Railway Suburban Lines.—The electrification scheme, covering forty miles of double track, has been designed on the third-rail continuous-current system, and what was formerly practically an hourly service on the routes dealt with is now a quarter-hourly service.

The system of train operation adopted is the Sprague Thomson-Houston multiple unit system. The main advantages of the multiple unit system are that trains of any length may be built up without affecting the efficiency of operation or diminishing the speed of the train.

In addition to the electric passenger train, electric locomotives are provided for dealing with the goods traffic.

Other Uses of Electrical Energy on the North-Eastern Railway.—Electricity is also used by the North-Eastern Railway for lighting and motive power at their passenger stations, locomotive works, and repairing shops.

Transmission System and Sub-stations.—The energy is generated at the power-stations as three-phase alternating current at a pressure of 6,000 volts, and is transmitted to five sub-stations, which are equipped with rotary converter sets of an aggregate capacity of 15,000 horse-power. Current is fed to the conductor rail as direct current at 600 volts.

Generating Station.—The generating station from which the current is obtained

[1] Published in the *Engineer*, September 9, 1904.

and which also supplies practically the whole of the manufacturers on the north bank of the Tyne, is the Carville power-station of the Newcastle-upon-Tyne Electric Supply Company, Limited. This station supplies power for probably a greater variety of purposes than does any other station in present operation. Its equipment consists of 20,000 horse-power of plant, made up of Parsons's turbo-alternators, two of which are of 7,000 horse-power, being the largest steam turbines yet constructed in this country.

Conclusion.—The ideal arrangement for power supply is, the authors suggested, that by which all the electrical requirements of an industrial neighbourhood are supplied from a single inter-connected power transmission and distributing system. Such systems are commercially possible in this country, due to (1) its density of population; (2) its cheap coal supply; and (3) the nature of its industries, and the waste power which is naturally produced by them.

On all load factors up to 30 per cent. a saving of 1*l.* per kilowatt on the capital expenditure has greater effect on the selling price of current than the reduction of the coal bill by 6 per cent. (coal being taken at 6*s.* per ton). It is therefore evident that if a steam station can be erected so as to cost 17*l.* less per kilowatt of plant than a station driven by water-power, electricity can be sold more cheaply from the former than from the latter. In fact, it is probable, absence of water-power notwithstanding, that this country could be supplied with electrical energy more cheaply than any other country in the world.

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3. *Testing Alternating Current Induction Motors by a Hopkinson Method.*[1] *By* W. E. Sumpner *and* R. W. Weekes.

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4. *Energy Losses in Magnetising Iron.*[2] *By* W. M. Mordey *and* A. G. Hansard.

The authors called attention to the magnitude of the total amount of energy lost in magnetising iron in electrical machinery, estimating that in this country alone between 25,000 and 50,000 tons of coal are expended annually in keeping transformers magnetised, without including the magnetising losses in the armatures of alternators, dynamos, and motors.

The total losses, as measured by a wattmeter, in different thicknesses of iron of the same quality at different periodicities, are compared amongst themselves and with hysteresis tests made by other methods, and also the total losses in the same sample of iron at different temperatures, and the following general conclusions are arrived at: (1) In determining the magnetic quality of iron sheets, eddy-current losses, though often neglected, are by no means negligible, and are often as important as hysteresis; (2) the simple laws generally assumed to be followed by hysteresis and eddies are found, as often as not, to be rather widely departed from —*e.g.*, the total loss of energy, including eddies and hysteresis, often does not follow a $B^{1\cdot6}$ curve; and (3) consequently, with such a variable material as iron, the only satisfactory method of predicting losses is to make wattmeter tests of samples as nearly as possible under the working conditions.

Fig. 4 shows the total loss (hysteresis and eddies) in three thicknesses of iron—viz., ·0136 inch (·34 mm.), ·0189 inch (·47 mm.), and ·0254 inch (·61 mm.). This iron was all of one make. It was tested in transformer form at 50 periods and 100 periods per second, and at magnetisations suitable for transformer work and, to some extent, for dynamo work. The tests were made on an alternator having practically a sine curve. The samples were large—nearly 12 lb. each—the total

[1] Published in the *Electrical Engineer*, August 26, 1904.

[2] Printed in full in the *Electrical Engineer*, August 26, 1904, N.S. xxxiv. p. 297, and in the *Electrician*, September 2, 1904, lviii. p. 790.

energy loss being measured by a wattmeter. The hysteresis curves of this figure are based on a single test by a Ewing tester, for each sample of iron, worked out for 50~ and 100~ by comparisons with standards tested at 4,000 B, 100~ by ballistic galvanometer, the values at other B's being calculated on the Steinmetz $B^{1·6}$ ratio. The results need but little explanation to show the marked increase of loss with thickness.

These tests do not lend any support to the common belief that with ordinary degrees of lamination the eddy-current loss is reduced to negligible proportions. On the contrary, they show that the eddies loss is of the same order of importance as that due to hysteresis.

In calculating losses in iron for hysteresis tests, it is usual to assume that the rate of increase of eddy loss is proportional to the square of the thickness, the square of B and the square of the periodicity. An examination of the curves will show that in some respects these assumptions are not confirmed, thus:—

Thickness.—As between ·0136 and ·0189 inch, the eddy loss on the average is practically proportional to (thickness)^2, but as between ·0136 and ·0254 inch the average increase is about 30 per cent. less than the ratio of (thickness)^2, the increase being from 1 to about 2·4 instead of 1 : 3·5.

Eddies and B.—On the average the increase is substantially in accordance with the B^2 assumption.

Eddies and Periods.—The increase is rather less than the usual (periods)^2 assumption, being about 1 : 3·4 instead of 1 : 4.

The departure from the (thickness)^2 and (periods)^2 ratios of increase may reasonably be explained by supposing the eddy circuits to have self-induction.

The six total loss curves will be found to be rather steeper than $B^{1·6}$ curves. It often happens, however, that the curves of total loss are substantially $B^{1·6}$ curves, showing that in such cases the eddy constituent of the loss as well as the hysteresis closely follows the Steinmetz ratio.

Fig. 2 illustrates this. It gives the total loss, measured by wattmeter, of iron ·014 inch thick at 50 periods and at 100 periods and at various B's. The wattmeter readings are shown by round points, the points marked + being $B^{1·6}$ values.

This iron is representative of good transformer iron, now obtainable in quantities in England. Slightly better iron is sometimes got, but not often nor in large quantities.

Fig. 5 shows the result of total loss test by wattmeter of some ·0124 inch iron at two temperatures—viz., 40° F. and 167° F., together with a ballistic galvanometer test for hysteresis of the same iron taken at 2,000, 5,000, and 8,000 B. The three hysteresis values so obtained fall on a $B^{1·6}$ curve.

It will be found that the total loss curves (at the two very different temperatures mentioned) also follow $B^{1.6}$ curves, which are shown thus +, the wattmeter readings being shown by the round points.

Although the total loss generally closely approximates to $B^{1·6}$ curves, it may be either less or more steep than such curves. Fig. 4 shows examples of somewhat greater steepness; figs. 2 and 5 show coincidence with $B^{1·6}$ curves; and the authors have also found curves less steep. Examples of the latter may be seen, *e.g.*, in the total loss tests given in Kapp's 'Transformers' (1896, p. 23) of iron carried up to nearly 7,000 B, which will be found on examination to be less steep than $B^{1·6}$ curves. The table of hysteresis values (going up to 15,000 B) given at p. 108 of Ewing's 'Magnetic Induction in Iron' (3rd edition) will also, on examination, be found to form a curve perceptibly less steep than $B^{1·6}$. As on the whole, however, the evidence is in favour of the Steinmetz ratio for the hysteresis (though by no means invariably so), it is probable that the variations in the forms of the total loss curves are due to differences in the ratio of increase of the eddy currents. The various results point to the need for making wattmeter tests of total loss in iron under working conditions, and that it is not safe to rely only on hysteresis tests.

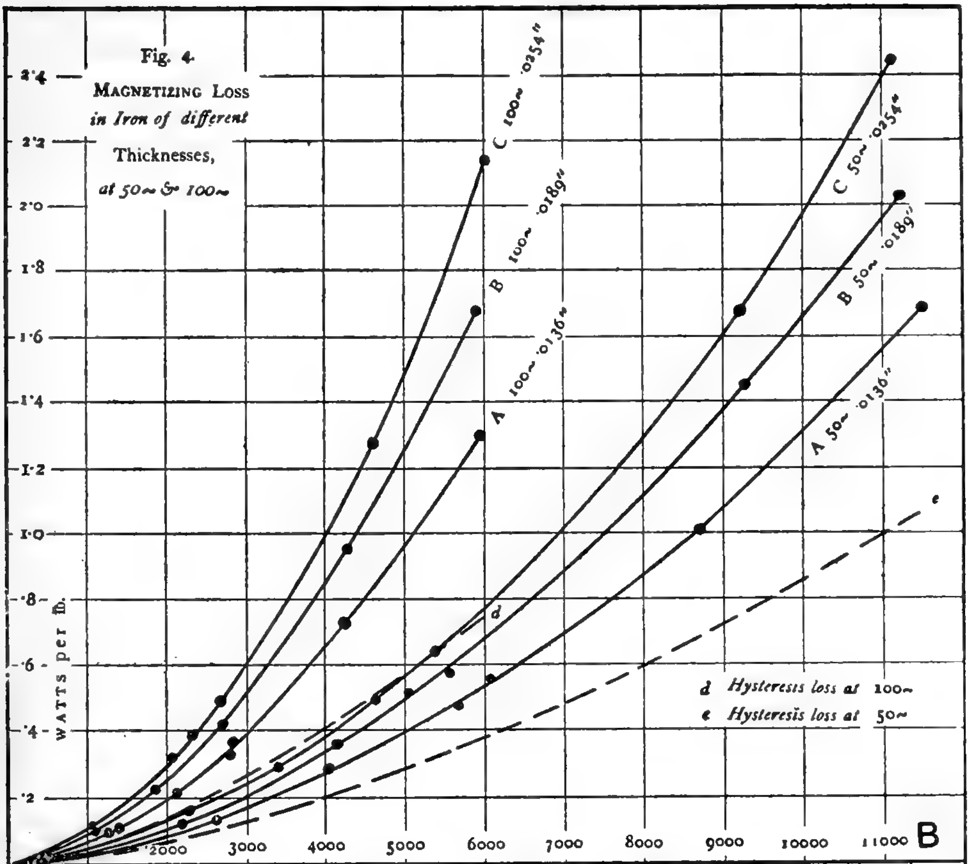

Fig. 4.
MAGNETIZING LOSS
in Iron of different
Thicknesses,
at 50~ & 100~
C 100~ ·0254"
B 100~ ·0189"
A 100~ ·0136"
C 50~ ·0254"
B 50~ ·0189"
A 50~ ·0136"
d Hysteresis loss at 100~
e Hysteresis loss at 50~
WATTS per lb.
2·4
2·2
2·0
1·8
1·6
1·4
1·2
1·0
·8
·6
·4
·2
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
B

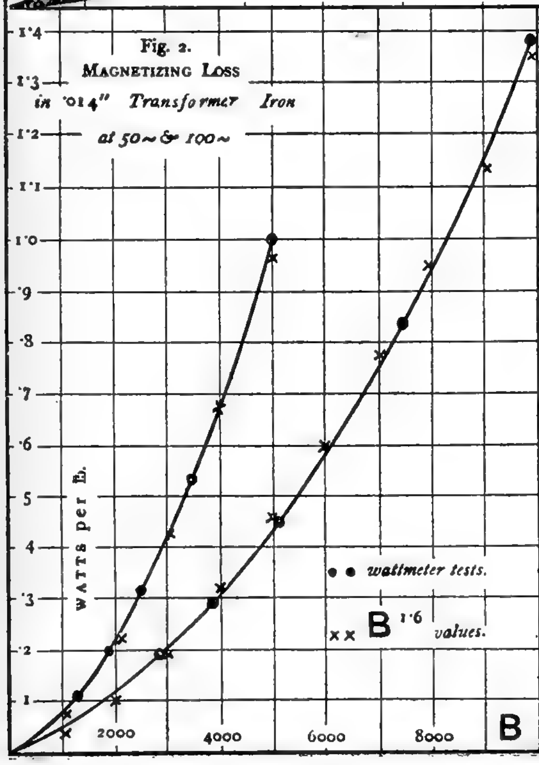

Fig. 2.
MAGNETIZING LOSS
in ·014" Transformer Iron
at 50~ & 100~
● ● wattmeter tests.
x x B 1·6 values.
WATTS per lb.
1·4
1·3
1·2
1·1
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
2000
4000
6000
8000
B

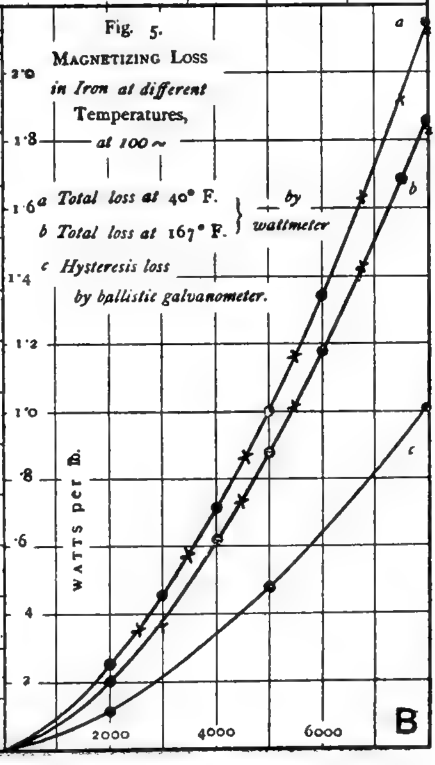

Fig. 5.
MAGNETIZING LOSS
in Iron at different
Temperatures,
at 100~
a Total loss at 40° F.
b Total loss at 167° F.
by wattmeter
c Hysteresis loss
by ballistic galvanometer.
WATTS per lb.
2·0
1·8
1·6
1·4
1·2
1·0
·8
·6
·4
·2
2000
4000
6000
B

5. *Distribution of Magnetic Induction in Multipolar Armatures.*[1] *By* W. M. Thornton.

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6. *On Large Bulb Incandescent Electric Lamps as Secondary Standards of Light.*[1] *By* Professor J. A. Fleming, *M.A., D.Sc., F.R.S.*

The importance of possessing a secondary standard of light which shall be at once portable, convenient, and constant is generally acknowledged, and the choice lies between some form of flame standard and some form of incandescent standard.

It is known that the candle power of a flame standard is affected by the variation of moisture in the air, atmospheric pressure, and carbonic acid, and that even in well-ventilated rooms changes in atmospheric moisture and pressure may cause variations to the extent of 4 per cent. in the candle power of a flame standard.

For the last eight years the author has employed as a secondary standard of light a form of carbon filament incandescent lamp having a specially large bulb and a filament prepared in a certain manner. The size of the bulb prevents any sensible deposit of carbon upon it, and the particular preparation of the filament by ageing it previously to mounting in the bulb prevents variations in candle power provided the lamp is used in a particular manner and only for a short time on each occasion. These large bulb lamps are not intended for continuous use, but only to be employed in setting or adjusting the distance of another lamp from the photometer disc in a photometer, so as to produce on the disc a predetermined illumination. The lamp to be measured is then substituted for the standard lamp, and by this process of double weighing all errors due to want of symmetry in the photometer are eliminated. If only used in the above manner the standard lamps may be used for hundreds of times without being in operation altogether for more than a few hours, and by comparing a number of these standards with one another it is possible to preserve a standard of light with great constancy. The illuminating power of these lamps is not affected by changes in moisture and atmospheric pressure, and the experiments described in the paper show that they are not sensibly affected by change in atmospheric temperature. The light of the lamp is therefore determined only by the current passing through it, and this can be measured easily with an accuracy of one part in a thousand by means of a potentiometer. Hence, when the filament is traversed by the same current, the lamp gives the same light. The author has therefore devised an arrangement consisting of a large bulb lamp united with a current measuring instrument and a variable resistance. This instrument, however, is not graduated directly to read current, but is graduated to read candle power; hence all that has to be done is to place the instrument on a circuit supplying a steady electromotive force and vary the current through the lamp by means of a rheostat until the needle of the current-measuring instrument indicates a certain candle power. The lamp then has a known candle power in a certain direction. Such an arrangement, although not sensitive enough for laboratory purposes, is quite sufficiently accurate and very convenient for the workshop comparison of ordinary glow lamps. For more accurate observations, however, a potentiometer must be employed, since the current or the voltage on the terminals of the lamp must be determined to at least one part in a thousand, if the candle power is to be correct within half per cent. If incandescent lamps are compared directly with flame standards, the latter not being corrected for atmospheric moisture and pressure, then differences to the extent of even 4 or 5 per cent. may be found in measuring the candle power of the incandescent lamp on different occasions and in different places. As this difference amounts to about one candle in twenty-five, it is far greater than possible errors in observations made with due care.

For the purpose of bringing into agreement photometric measurements made

[1] Published in the *Electrician*, August 26, 1904.

in different parts of the world, these large bulb standard photometric lamps have proved very useful, and also they have proved of utility in obtaining the proper coefficients for the correction of the candle power of flame standards for atmospheric moisture and temperature.

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7. *Some Investigations on the Ten-candle Power Harcourt Pentane Lamp made at the National Physical Laboratory.*[1] *By* CLIFFORD C. PATERSON.

This paper gave briefly the results of investigations carried out at the National Physical Laboratory in order to determine changes in the illuminating power of the ten-candle Harcourt lamp due to variation

(i.) In barometric pressure.
(ii.) In the quantity of water vapour present in the air.

When photometric comparisons are made between the pentane standard and a source of light unaffected by atmospheric conditions, as, for instance, an electric glow lamp, errors of the order of 5 per cent. may be introduced into candle-power measurements if corrections are not made for the hygrometric and barometric conditions existing at the time.

In order to ascertain the amount of variation, photometric comparisons were made against two large bulb Fleming-Ediswan electric standard glow lamps. The double comparison method only was employed, and the two electric lamps used to standardise a comparison glow lamp anew for each experiment, so that it was only necessary to burn the standards for five or ten minutes at a time.

It is found convenient to state humidity volumetrically, as the number of litres of water vapour to a cubic metre of pure dry air, at the barometric pressure existing at the time; so that if

b = Reading of barometer in mm.,
e = Aqueous pressure,
e_1 = Vapour tension of carbon dioxide present in the atmosphere,

the litres of water vapour per cubic metre of pure air

$$= \frac{e}{b - e - e_1} \times 1{,}000.$$

Upwards of sixty observations have been made on different days over a range of humidity varying from five to twenty litres per cubic metre, which are about the limits obtained under ordinary conditions in a well-ventilated photometer room; eighty per cent. of these, when corrected by means of the formula, fall within + or − $\frac{1}{2}$ per cent. of ten-candle power.

The barometric pressure in these observations has varied from 739 to 780 mm. of mercury, so that, applying the method of least squares for these two variables, the following formula has been obtained for correcting the candle-power of the lamp to the standard atmospheric conditions of 760 mm. of mercury and ten litres of water vapour per cubic metre of pure dry air.

$$\text{Candle power} = 10 + 0{\cdot}066\ (10 - \epsilon) - 0{\cdot}008(760 - b),$$

where ϵ is the humidity as explained above and b the height of the barometer in mm.

From this it will be seen that a variation of one litre per cubic metre in the moisture causes a variation in candle-power of about 0·7 per cent., and that 10 mm change in barometric pressure brings about an alteration of 0·8 per cent. in the illuminating power of the lamp.

The standard humidity of ten litres per 1,000 has been fixed upon as being the mean value for three years found at Kew Observatory. The figure is also borne out by observations made at the Meteorological Office in Victoria Street, London.

[1] Published in the *Electrician*, August 26, 1904.

TUESDAY, AUGUST 23.

The following Report and Papers were read :—

1. *Report on the Tidal Régime of the River Mersey.*
See Reports, p. 318.

2. *The Control of the Nile.*[1] *By* Major Sir HANBURY BROWN, *K.C.M.G.*

3. *A Universal Testing Machine of* 300 *tons for Full-sized Structural Members. By* J. H. WICKSTEED, *Pres.I.Mech.E.*

The machine will admit a column or strut 88 feet long, 3 feet 3 inches square in cross-section. It will admit a beam 3 feet 3 inches broad, 6 feet 6 inches deep, and 20 feet between supports. It will shear a bar of mild steel 8 inches by $2\frac{1}{2}$ inches. It will break a steel wire rope 9 inches in circumference.

It makes autographic stress-strain diagrams in all these tests. The sensibility of the machine with a pull of 100 tons is one in 10,000.

A list was then given of other large machines.

The purpose of the machine is not simply that of testing the strength of material itself, but it is for testing the strength of a full-sized member of any structure; that is, the strength which results from the disposition of the material in the sections and in the proportions of, for example, a strut, an eye-link, or a beam. The reason for employing a machine for the purpose of making tests instead of loading on full loads directly upon the specimen is, that for no reasonable cost could you possibly make experiments with heavy loads applied in bulk. Three hundred tons of accurate dead-weights would themselves cost about 2,400*l.*; their application to the specimen would be so tedious that each experiment would cost as much in time and in labour as 100 experiments conducted in the machine to be described, where the full load is applied through hydraulic pressure and balanced by small accurate weights acting through levers and knife-edges. To minimise time and labour in making tests on various forms of structural members, this machine has been so designed as to be applied, without any change of apparatus, either to thrusting strains or pulling strains, and this is accomplished by making the straining frame in the form of a large trough, which is pushed forward by a hydraulic plunger and which carries with it a straining head capable of being locked at any part of its length. This trough, hydraulic ram, and cylinder are completely surrounded by a balancing framework of tension rods and cross-heads, and this enables the straining cross-head to apply its force to one part of the balancing-frame which surrounds it for compression tests, and to another part of the balancing-frame for tension tests. Wherever the force may be applied to the balancing-frame, it is delivered to the levers and poise weights where it is measured. Besides the facility for bringing forces to bear either in compression or tension, it is requisite that no labour should be involved in arranging the machine to take in long or short pieces, and this is accomplished by mounting the straining head upon wheels, so that it can be quickly run to any part of the moving trough and locked there by bolts, which can be shot with the same facility that you would shoot the bolts in the door of a strong-room.

An article from 'Le Génie Civil' was quoted, with remarks on the machine from the pen of M. Breuil, Chef de la Section des Métaux du Laboratoire des Arts et Métiers.

4. *The Effect of Rapidly Alternating Stresses on Structural Steels.*[2] *By* Professor J. O. ARNOLD.

[1] Published in *Public Works*, January 1905.
[2] Published in the *Engineer*, September 2, 1904.

5. *The Production of Magnetic Alloys from Non-magnetic Metals.* *By* R. A. Hadfield.

Having some years ago produced a non-magnetic iron alloy known as 'manganese steel,' I was much interested in learning that with the same metal, manganese, which had enabled me to obtain a practically non-magnetic iron alloy, it had been found possible to produce a magnetic copper alloy.

I have had communications with Dr. F. Heusler, who has given me much interesting information. I have myself also produced some of this alloy, as exhibited to-day.

It is of course well known that the metals copper, aluminium, and manganese, are non-magnetic. It is, therefore, to say the least, surprising to find that, combined in certain proportions, they produce an alloy having quite considerable magnetic properties.

It may be first mentioned that no combination of copper with aluminium produces a magnetic alloy; the peculiar change noticed, therefore, must be ascribed entirely to the presence of manganese metal—the same metal which in manganese steel produces the profound change in iron, converting it from its well-known magnetic to non-magnetic condition.

As it was thought that perhaps the manganese metal under certain conditions might show some reversibility, as is the case with certain iron-nickel alloys which, whilst being non-magnetic at ordinary temperatures, become magnetic at low temperatures—60 to 80°C.—Sir James Dewar himself submitted the manganese metal I used in producing the alloy exhibited to the temperature of liquid air. No change was found to occur; the metal remained as non-magnetic as at ordinary temperatures. This, of course under the same test, was found to be the case with the copper and aluminium used in my experiments.

The alloy exhibited contains 60 per cent. copper, 25 to 27 per cent. manganese, and 12 per cent. of aluminium. The manganese metal used contained about 92 per cent. manganese, the rest being 6 to 7 per cent of silicon, ·5 to 1 per cent. of carbon, and probably 0·50 per cent. of iron. But Dr. Heusler has shown that with absolutely no iron present the magnetic qualities are exactly the same.

Another very curious point is, that whilst it must be the manganese which confers the magnetic properties, the 'reversibility,' so to speak, is brought about by the aluminium.

For example, with the manganese fairly constant 25 to 28 per cent., and the aluminium varying from 3 to 14 per cent., the magnetisability with 3 per cent. is nil; 5 per cent. confers a little; 10 per cent. is still more; the maximum being reached with 14 per cent. aluminium:—

Specimen Numbers.	Analysis per cent.			H = (Magnetising Force). 20, 40, 100, 150.
	Mn.	Al.		
34	28	3·6	B = Magnetic induction.	Unmagnetisable.
35	28	5·7		Very slightly magnetisable.
36	26	9·6		2,220, 2,670, 3,200, 3,470.
32	26	14·6		4,500, 4,850, 5,380, 5,550.
33	25	13·8		3,580, 4,075, 4,645, 4,900.

Dr. Heusler states that the magnetisability of the alloy will increase with an increased percentage of aluminium, the maximum for any stated percentage of the manganese being attained when the aluminium percentage amounts to, roughly, one-

half of the percentage of manganese, or, in other words, when the alloy contains one atom of aluminium to one atom of manganese.

It may be added that the alloy exhibited is, unfortunately, very brittle, and all attempts to forge it, cold or hot at various temperatures, even only at dull red, have been unsuccessful.

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6. *Indicator Tests on a small Petrol Engine.* *By* Professor H. L. Callendar, *F.R.S.*

WEDNESDAY, AUGUST 24.

The following Papers were read:—

1. *Side Slip in Motor Cars.*[1] *By* Horace Darwin, *F.R.S., and* C. V. Burton.

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2. *An Electric Temperature Alarm.*[2] *By* Horace Darwin, *F.R.S.*

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3. *The Electrical Conductivity of certain Aluminium Alloys as affected by Exposure to London Atmosphere, and a Note on their Micro-structure.* *By* Professor Ernest Wilson.

This paper dealt with the effect upon electrical conductivity of exposing light aluminium alloys to London atmosphere. During three years' exposure the copper-aluminium alloys have gradually diminished total conductivity to a greater extent the greater the percentage of copper. Of the nickel-copper-iron aluminium alloys, which show such remarkably increased tensile strength as compared with good commercial aluminium, those which are richer in nickel have diminished total conductivity least. The manganese-copper aluminium alloys have suffered comparatively little diminution in total conductivity, and one of them has comparatively high tensile strength. A 1·2 per cent. iron aluminium alloy has shown very little diminution in electrical conductivity. It was thought that an examination of the structure of these alloys by aid of micro-photography might throw some light on the great difference which exists between some of their physical properties. For instance, a nickel-copper aluminium alloy has 1·6 time the tensile strength of ordinary commercial aluminium. Under a magnification of 800 diameters practically no structure could be discovered. Considering the remarkable crystalline structure exhibited by ordinary commercial aluminium near the surface of an ingot, when allowed to solidify at an ordinary rate, the want of structure in these alloys must be attributed to the process of drawing down. The inference is that the great difference which exists between their tensile strengths and other qualities is not due to variation in structure. The experiments in micro-photography have been carried out by aid of a portion of the Government grant voted to the author by the Council of the Royal Society.

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4. *The proposed Barrage of the River Thames.* *By* James Casey.

Any engineering scheme that offers a solution to the many problems involved in attempts to remove the inconveniences and difficulties attending the navigation of the river Thames, with a view to the proper control of the enormous volume

[1] Published in *Engineering*, September 9, 1904.
[2] Published in *Engineering*, March 10, 1905.

of commerce flowing into and out of the Port of London, has claims on the attention of every individual concerned in the commercial prosperity of the kingdom. I propose to meet these difficulties by constructing across the river from Gravesend to Tilbury a dam or barrage similar to that across the Nile; the foundation of the dam, constructed of granite and mass concrete, will be in the chalk, and on the top will be a roadway for carriage and ordinary road traffic; the dam will be provided with locks, four in number, each provided with internal gates in addition to the outer ones, in order that these locks may be worked in long or short lengths to suit the traffic. The lengths provided in this way will be 300 feet, 500 feet, 700 feet, and 1,000 feet, and the widths from 80 feet to 100 feet, which will suit both present and future steamships. It will be easy to lock the number of vessels passing up and down the river (which averages 220 per day), many of which are small craft; but the lock accommodation could lock three times the number if necessary; the great advantage to the shipping interest being that, instead of waiting tides at Gravesend, each vessel as she arrives can be locked in a few moments without delay.

The lock will be worked by electricity generated and obtained from dynamos operated by the fall of water flowing over the dam; a pilot-tower will be fixed from which the traffic will be worked and regulated and locks, movable bridges, &c., controlled.

A system of signalling from the barrage to the upper reaches of the river will be employed to notify any heavy freshet coming down the river, so that the sluices may be regulated to maintain the required level in the river to the proposed depth of 30 feet, as well as to secure the approaches to the locks.

The dam will provide a fresh-water basin to the Trinity high-water mark, and the present docks will be accessible at all hours of the day or night irrespective of tides. The unsightly and foul-smelling mud-banks now laid bare twice in the twenty-four hours will no longer disfigure the river; a fresh-water lake forty miles long will be available for boating and pleasure traffic—thus opening up a new source of recreation and physical exercise to the teeming millions of the metropolis—and provide a supply of water for the new Water Board without going to Wales at a cost of not less than 24,000,000*l.* for an additional supply; the extension of works on both banks of the river will afford facilities for employment to our working population, and enable them to spread and so relieve the congestion of the ever-increasing East End population.

In connection with the dam I propose to construct a tunnel, which will be formed in the solid monolith as the work proceeds, connected with the existing railways in Essex and Kent, which will enable the military and naval authorities to utilise their base of warlike stores in Woolwich, Sheerness, and Chatham on our north-east coast, should the necessity arise, thus saving both time and expense.

The dam from a strategic point of view affords a valuable solution of the question of the Thames defence by effectually blocking the river, and prevents the approach of submarine or other 'raiders'; incidentally it provides a grand harbour for the fleet and a protection against invaders; and, lastly, the cost is only 4,000,000*l.*, as against 37,000,000*l.* proposed, besides which must be set off prospective enormous outlay for water-supply, reservoirs, and other matters, which will become unnecessary if this scheme is adopted.

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5. *Testing Alternate-current Motors by Continuous Current.* *By* WILLIAM CRAMP, *A.M.I.E.E.*

Since an alternating magnetic field may be resolved into two equal rotating fields, each of 0·7 times the value of the original field, it follows that there is a close connection between the behaviour of an alternate-current motor on its normal supply and that of the same motor having the stator supplied with a continuous current of the proper value, while the rotor is driven round at the proper speed by some independent means.

As an example of this consider a repulsion motor. It may be shown that such a motor is a special case of the single-phase alternator, whence the laws govern-

ing the value and phase of its rotor current are perfectly well known. (See 'Electrical Engineer,' August 12, 1904.)

If the motor is arranged so that its stator may be excited with a continuous current equal to $1{\cdot}41\ \mathrm{A}\cos 2d$ amperes (where A is the normal magnetising current of the motor, d the angle between the brush line and the polar axis), and the rotor is arranged to be driven by a continuous-current motor, then the following tests may be performed:—

I. Calibrate the C.C. motor, so that the power required to drive it at any particular speed is known.

II. Connect it to the A.C. motor shaft (the A.C. motor not being excited), and measure the power required at various speeds (friction and windage).

III. Drive as above (in II.), but with the rotor on open circuit and stator excited with continuous current, as explained above. (Rotor hysteresis and eddy losses, hence also stator hysteresis and eddy loss.)

IV. Close the rotor circuit by connections which revolve with the rotor, and excite (as in III.), and run at what would be synchronous speed. This gives the rotor current at standstill (if desired, for various values of d). It also gives, if the speed is varied, the rotor power factor at standstill—a most important point.

V. With the same continuous current the resistance of rotor and stator may be measured.

Thus all the losses of the motor are completely known, as well as the rotor current and power factor, and the performance of the motor may be predicted exactly.

The method enables a very satisfactory test to be made, when alternating current of the right voltage and frequency is not available, which is an important point, especially in England, where the frequencies are so varied as to make it necessary to have a great deal of apparatus to test even a moderate run of motors. *No wattmeter is necessary*, which is another advantage, and in technical colleges it will be found that students will grasp the working of alternate-current apparatus in general, if such methods are used to bring home the close connection which exists between it and similar direct-current machinery.

A model of the apparatus was shown.

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6. *The Action of Lightning Strokes on Buildings.*[1] *By* Killingworth Hedges.

[1] Published in the *Electrical Engineer*, September 2, 1904.

Section H.—ANTHROPOLOGY.

President of the Section—Henry Balfour, M.A.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

It has frequently been remarked, and not without some justification, that Anthropology is an exceedingly diffuse science, and that it lacks the compactness and relatively well-defined field of enterprise enjoyed by most other sciences. This characteristic has even been employed by many as an argument against regarding Anthropology as a subject of any considerable value for educational purposes, the suggested lack of cohesion being thought to militate against this science ever being allowed to occupy a similar position in the educational curricula and examination systems of this country as that to which the older sciences have for the most part been admitted. For my own part, I cannot but consider the validity of this argument as open to question. The term Anthropology, used in its unrestricted and, as I venture to think, proper sense, does, I readily admit, embrace a vast and varied field, and it inevitably overlaps, and even wanders far and at times freely into the domains of other sciences. How should it and how can it be otherwise? We, surely, would be guilty of grievously undervaluing and paying scant respect to our genus were we to imagine that the science devoted to its comprehensive study could be otherwise than far-reaching—call it diffuse if you will—and that it could be expected to avoid driving its roots deeply into other sciences whose chief practical interest lies, after all, in their adaptability to the service of Man.

In admitting the partial justice of the accusation as regards diffuseness, Anthropology, it seems to me, is really pleading guilty to the possession of an educational quality of which it may rather boast than feel ashamed. A science which is so far-reaching, and yet whose nucleus or focussing point is so well defined, seems of itself to furnish the materials in great part for a liberal education, if properly handled, and to lend itself to the preparation of the inevitable syllabuses, adapted to the different grades both of general education and of higher scholarship.

I readily admit that the *word* Anthropology is unfortunately cumbersome; but it would seem to be inevitable, since no one has yet provided the science with a compact general name which may serve as an efficient substitute; and, since we must retain it, we may at least expect the word to work for its polysyllabic existence, by covering a wide area and serving as the most general term denoting the study of Man in a wide and all-embracing sense.

It is not my purpose to discuss here the educational value of Anthropology, but frankly and even gladly to admit that Anthropology, in spite of its late recognition as a distinct science worthy of encouragement, has in recent years progressed with rapid strides, and has already reached a stage of developmental progress at which it is necessary to differentiate the several branches of stud

which are included under the general science, and to adopt a classification which is ever becoming more complex as the various divisions become unwieldy and require subdividing. An extensive terminology has been growing up for the purpose of assigning appropriate names to the already fairly numerous divisions of the main subject. Anthropology is passing through the developmental stages which have been followed by the older sciences, and is merely following normal routine in advancing from the simple to the complex. With the increase of knowledge the elements which together constitute a given science necessarily develop individually as well as collectively, and the original science loses its primitive unity by becoming an ever-increasing aggregation of sub-sciences. This process of subdivision or branching is inseparable from the life-history of an active and progressive science.

The genesis, growth, and maturity of Section H reflects to some extent the development of the study of Anthropology. If we look back nearly sixty years, to a meeting of the Association held in Cambridge in 1845, we see that Ethnology was not mentioned at all in the programme and list of Sections, though one ethnological paper does certainly figure amongst those of the Zoological-Botanical group. We may, however, assume that at this meeting a start was made, and give to Cambridge due credit for having a distinct claim to the parentage of Section H. For, in the following year, 1846, we find in the list of Sections a definite *sub-Section* of Ethnology. Indeed, were we in doubt as to the parentage of the infant sub-Section, there is circumstantial evidence clearly indicating this ancient University city, in the subtle influence apparently exercised upon the mind of the parent by overpowering leanings towards applied mathematics, as manifested by the interesting and otherwise unaccountable fact that the 'sub-Section of Ethnology' was in that year humbly parasitic upon Section G, which was then, as now, devoted to 'Mechanics!'

From 1847 to 1850 the Ethnological sub-Section came under Section D (Zoology, Botany, and Physiology). In 1851 Ethnology appears in conjunction, and, apparently, on nearly equal terms with Geography; and so it remained in the year 1862, when the Association again had the privilege of meeting in Cambridge, that profound and ingenious student of Man, Mr. Francis Galton, being President of the dual Section. The Geographico-Ethnological combination lasted until 1868, after which, and until 1880, we find the prospective Section H replaced under the charge of Section D—Biology (which included Zoology, Botany, Anatomy, and Physiology).

The steadily growing vitality of the study of Man is very evident through all these years, from the list of papers read, and one may gather, from the way in which the sub-Section was transferred from Section to Section, that the infant was rapidly outgrowing its nurses, and becoming a troublesome handful. Typographical signs of adolescence, coupled with a yearning for independence, appear in 1883, when, glancing at the list of Sections, we see that, although Anthropology is still a 'Department of Biology,' not only is it the only 'department' specially announced under Section D, but the heading is printed in type of the same magnitude as that used for the Section itself. The printer proved to be a good prophet; for in the following year, 1884, at the meeting in Montreal, the inevitable occurred, and Anthropology blossomed out into the adult stage, and received the emancipation afforded by the assignment of an entire Section to itself, the 'Section H,' which has, I venture to think, thoroughly justified its existence ever since.

It may be doubted whether we have as yet reached the limit of expansion. The time is likely to come when Section H will be the parent of one or more vigorous sub-Sections, which, again, may repeat the developmental sequence, reaching at length maturity and discretion, and being perhaps allowed to set up for themselves as semi-independent Sections. The original title of a Section of the British Association may disappear entirely as such, after the sub-Sections comprised under it have received their full emancipation. This has happened in the case of Biology, which for some thirty years gave its name to Section D, but which finally gave way before the growth of its enterprising and very progressive offshoots (Zoology, Anthropology, Physiology, and Botany), which one after the

other developed into independent Sections. With this segregation of the various component elements of Biology, the old generalised title ceased to appear on the list of the British Association. This, perhaps, will be the fate of the term 'Anthropology,' as the growth of the subjects which have developed under the wing of this very comprehensive science gradually causes, for the sake of practical convenience, a number of subordinate titles to replace the time-honoured and inclusive term. Should it thus happen, in response to the growth of the science, that this term is destined to follow the far wider term 'Biology' into a position of dignified ease, we shall be wise to bear continually in mind that Anthropology is the main stem from which the various branches have sprung, and to whose nourishment and growth it should be the principal aim of their individual activities to contribute. In an age of ever-increasing specialization we may from time to time require a reminder of the fact that the true value of researches in the special fields of a science must be estimated by the degree to which their relationship to the whole can be and is rendered manifest. The work of specialists will necessarily lose half its value if there is a dearth of generalists who will gather together the threads and weave them into a substantial fabric, which shall show the importance of each individual piece of work to the progress of the science as a whole.

Once Anthropology became recognised as a definite science, and one worthy of encouragement, the number of its devotees increased steadily and apace, and the range of its work widened rapidly. Indeed, it would appear as though there were an almost feverish desire to make up for time lost through the phenomenal tardiness of the discovery of a seemingly obvious fact, which is that 'Man' is in very truth a 'proper study for mankind.' Energy is not wanting, though this feverishness is kept in rigid subjection by the chilling and reducing effect of starvation for want of funds. The lack of adequate financial support is painfully apparent in Great Britain when we compare the conditions prevailing here with those obtaining in other countries.

I will not endeavour to cope with the many and varied aspects of Anthropology and its complex ramifications, nor will I attempt to enumerate the many distinguished men of science to whose stimulating work we chiefly owe the progress already achieved in Anthropology; the more prominent pioneers are well known to you, and several, I am glad to say, are yet with us. Their works remain as important landmarks in the developmental record of the Science of Man. I have, instead, selected as my principal theme one branch of the subject. My main object is to review, necessarily briefly, *one* of the factors which have played a part in stimulating scientific inquiry into the past and present conditions of Man, and in furthering the development both of the scientific and the popular interests of Anthropology. I wish to confine myself to the consideration of the contribution of one man towards the subject, a contribution which is the more valuable since it deals with wide principles, and thus affords a basis upon which a vast army of students may found valuable work. It amounted to the establishment of a particular school of research into the history of human culture, into which fresh workers are constantly being attracted, and which has stood the test of time through half a century.

It was about the middle of last century that an officer in Her Majesty's Army began to apply the lessons which he had learnt in the course of some of his professional experimental work to studies pursued by him as a hobby in a far wider field of science. The story of the famous ethnographical collection of Colonel Lane Fox is well known, and I need but briefly refer to it. During his investigations, conducted with a view to ascertaining the best methods whereby the service firearms might be improved, at a time when the old Tower musket was being finally discarded, he was forcibly struck by the extremely gradual changes whereby improvements were effected. He observed that every noteworthy advancement in the efficiency, not only of the whole weapon but also of every individual detail in its structure, was arrived at as a cumulative result of a succession of very slight modifications, each of which was but a trifling improvement upon the one immediately preceding it. Through noticing the unfailing regularity of this process of gradual *evolution* in the case of firearms, he was led to believe that the same

principles must probably govern the development of the other arts, appliances, and ideas of mankind. With characteristic energy and scientific zeal Colonel Lane Fox began at once, in the year 1851, to illustrate his views and to put them to a practical test. He forthwith commenced to make the ethnological collection with which his name will always be associated, and which rapidly grew to large proportions under his keen search for material which should illustrate and perhaps prove his theory of progress by evolution in the arts of mankind.

Although as a collector he was somewhat omnivorous, since every artefact product fell strictly within his range of inquiry, his collection, nevertheless, differed from the greater number of private ethnological collections, and even public ones of that day, inasmuch as it was built up *systematically* with a definite object in view. It is unnecessary for me to describe in detail the system which he adopted in arranging his collection. His principles are well known to ethnologists, either from the collection itself or from his writings, more especially from the series of lectures which he gave at the Royal United Service Institution, in the years 1867–69, upon 'Primitive Warfare'; from his paper read before the Anthropological Institute in 1874 on 'The Principles of Classification, as adopted in the Arrangement of his Anthropological Collection,' which was then exhibited at the Bethnal Green Museum; from that portion of the *catalogue raisonné* of his collection which was published in 1877; and from numerous other papers dealing with special illustrations of his theory. Suffice it to say that, in classifying his ethnological material, he adopted a *principal* system of groups into which objects of like form or function from all over the world were associated to form series, each of which illustrated as completely as possible the varieties under which a given art, industry, or appliance occurred. Within these main groups objects belonging to the same region were usually associated together in *local* sub-groups. And wherever amongst the implements or other objects exhibited in a given series there seemed to be suggested a *sequence of ideas,* shedding light upon the probable stages in the evolution of this particular class, these objects were specially brought into juxtaposition. This special grouping to illustrate sequence was particularly applied to objects from the same region as being, from their local relationships, calculated better to illustrate an actual continuity. As far as possible the seemingly more primitive and generalized forms—those simple types which usually approach most nearly to *natural* forms, or whose use is associated with primitive ideas—were placed at the beginning of each series, and the more complex and specialized forms were arranged towards the end.

The primary object of this method of classification by series was to demonstrate, either actually or hypothetically, the origin, development, and continuity of the material arts, and to illustrate the variations whereby the more complex and specialized forms belonging to the higher conditions of culture have been evolved by successive slight improvements from the simple, rudimentary, and generalized forms of a primitive culture.

The *earlier* stages in these sequence series were more especially the object of investigation, the later developments being in the greater number of cases omitted or merely suggested. It was necessary for Colonel Lane Fox to restrict the extent of the series, any one of which, if developed to the full extent, would easily have filled a good-sized museum. The earlier stages, moreover, were less familiar, and presented fewer complications. The general principles of his theory were as adequately demonstrated by the ruder appliances of uncivilized races as by the more elaborate products of peoples of higher culture; and, moreover, there was doubtless a great attraction in attacking that end of the development series which offered a prospect at least of finality, inasmuch as there was always a chance of discovering the absolute origin of a given series. Hence the major part of his collection consisted in specimens procured from savage and barbaric races, amongst whom the more rudimentary forms of appliances are for the most part to be found.

The validity of the general views of Colonel Lane Fox as to evolution in the material arts of Man was rapidly accepted by a large number of ethnologists and others, who were convinced by the arguments offered and the very striking evidence displayed in their support. I have heard people object to the use of the

term 'evolution' in connection with the development of human arts. To me the word appears to be eminently appropriate, and I think it would be exceedingly difficult to find one which better expresses the succession of extremely minute variations by means of which progress has been effected. That the successive individual units of improvement, which when linked together form the chain of advancement, *are* exceedingly small is a fact which anyone can prove for himself if he will study *in detail* the growth of a modern so-called 'invention.' One reason why we are apt to overlook the greater number of stages in the growth of still living arts is that we are not as a rule privileged to watch behind the scenes. Of the numberless slight modifications, each but a trifling advance upon the last, it is but comparatively few which ever meet the eye of the public, which only sees the more important stages; those, that is to say, which present a sufficiently distinct advance upon that which has hitherto been in use to warrant their attracting attention, or, shall we say, having for a time a marketable value. The bulk of the links in the evolutionary chain disappear almost as soon as they are made, and are known to few, perhaps none, besides their inventors. Even where the history of some invention is recorded with the utmost care it is only the more prominent landmarks which receive notice; the multitude of trifling variations which have led up to them are not referred to, for, even if they be known, space forbids such elaborately detailed record. The smaller variations are, for the most part, utterly forgotten, their ephemeral existence and their slight individual influence upon the general progress being unrecorded at the time, and lost sight of almost at once. The immediately succeeding stage claims for the moment the attention, and it again in its turn becomes the stepping-stone upon which the next raises itself, and so on.

Before proceeding further, let me give as briefly as I can an example of a development series worked out, in the main, upon the general line of inquiry inaugurated by Colonel Lane Fox. It is commonly accepted as a fact, which is borne out by tradition, both ancient and modern, that certain groups of stringed instruments of music must be referred for their origin to the bow of the archer. The actual historical record does not help us to come to a definite conclusion on this point, nor does the direct testimony of archæology, but from other sources very suggestive evidence is forthcoming. A comparative study of the musical instruments of modern savage and barbaric peoples makes it very clear to one that the greater portion of the probable chain of sequences which led from the simple bows to highly specialized instruments of the harp family may be reconstructed from types still existing in use among living peoples, most of the well-defined early stages being represented in Africa at the present day.[1] The native of Damaraland, who possesses no stringed instrument proper, is in the habit of temporarily converting his ordinary shooting-bow into a musical instrument. For this purpose he ties a small thong loopwise round the bow and bow-string, so as to divide the latter into two vibrating parts of unequal length. When lightly struck with a small stick the tense string emits a couple of notes, which satisfy this primitive musician's humble cravings for purely rhythmic sound. Amongst many other African tribes we find a slight advance, in the form of special rather slightly made bows constructed and used for musical purposes only. In order to increase the volume of sound, it is frequently the custom amongst some of the tribes to rest the bow against some hollow, resonant body, such as an inverted pot or hollow gourd. In many parts, again, we find that the instrument has been further improved by *attaching* a gourd to the bow, and thus providing it with a permanent resonating body. To achieve greater musical results, it would appear that somewhere in Africa (in the West, I suspect) two or more small bows were attached to a single gourd. I have, so far, been unable to trace this particular link in Africa itself, but, curiously enough, this very form has been obtained from Guiana. It may be thought that I am applying a breaking strain to the chain of evidence when I endeavour to work an instrument

[1] *The Natural History of the Musical Bow*, by H. Balfour Clarendon Press, Oxford.

from South America into an African developmental series. But, when we recall the fact that evidence of the existence of *indigenous* stringed instruments of music in the New World has yet to be produced, coupled with the certain knowledge that a considerable number of varieties of musical instruments, stringed and otherwise, accompanied the enforced migration of African natives during the days of the slave trade, and were thus established in use and perpetuated in many parts of the New World, including the north-east regions of South America, we may, I think, admit with some confidence that in this particular instance from Guiana to Guinea is no very far cry, and that the more than probable African origin of this instrument from South America gives it a perfect claim to take its place in the African sequence. I still anticipate that this type of instrument will be forthcoming from some hinterland region in West Africa. Were *no* evidence at all forthcoming of such a form, either in past or present, we should be almost compelled to infer that such a one had existed, as this stage in the sequence appears to be necessary to prevent a break in the continuity of forms leading to what is apparently the next important stage, represented by a type of instrument common in West Africa, having five little bows, each carrying its string, and all of which are fixed by their lower ends into a box-like wooden resonator. This method of attaching the bows to the now improved body of the instrument necessitates the lower attachment of the strings being transferred from the bows to the body, so that the bow-like form begins to disappear. The next improvement of which there is evidence from existing types consists in the substitution of a single, stouter, curved rod for the five little 'bows,' all the five strings being serially attached to the upper end of the rod, their lower ends to the body as before. This instrument is somewhat rare now, and it may well be a source of wonder to us that it has survived at all (unless it be to assist the ethnologist), since it is an almost aggressively inefficient form, owing to the row of strings being brought into two different planes at right angles to one another. The structure of this rude instrument gives it a quaintly composite appearance, suggesting that it is a banjo at one end and a harp at the other. This is due to the strings remaining, as in the preceding form, attached to the resonating body in a line disposed *transversely*, while the substitution of a single rod for the five 'bows' has necessitated the disposal of their upper attachments in a *longitudinal* series as regards the longer axis of the instrument. Inefficient though it be, this instrument occupies an important position in the apparent chain of evolution, leading on as it does through some intermediate types to a form in which the difficulty as regards the strings is overcome by attaching their *lower* ends in a longitudinal series, and so bringing them into the same plane throughout their length. In this shape the instrument has assumed a harp-like form—a rude and not very effective one, it is true, but it is none the less definitely a member of the harp family. The modern varieties of this type extend across Africa from west to east, and the harps of ancient Egypt, Assyria, Greece, and India were assuredly elaborations of this primitive form. The Indian form, closely resembling that of ancient Egypt, still survives in Burma, while elsewhere we find a few apparently allied forms. In all these forms of the harp, from the rudest Central and West African types to the highly ornate and many-stringed examples of Egypt and the East, one point is especially noteworthy. This is the invariable *absence of the fore-pillar*, which in the modern harps of Western Europe is so important, nay, essential, a structural feature. In spite of the skill and care exercised in the construction of some of the more elaborate forms, none were fitted with a fore-pillar, the result being that the frame across which the strings were stretched was always weak and disposed to yield more or less to the strain caused by the tension of the strings. This implied that, even when the strings were not unduly strained, the tightening up of one of them to raise its pitch necessarily caused a greater or less slackening of all the other strings, since the free end of the rod or 'neck' would tend to be drawn slightly towards the body of the instrument under the increased tension. One can picture the soul-destroying agonies endured by two performers upon these harps when endeavouring, if they ever did so, to bring their refractory instruments into unison, while, as for the orchestral music of the old Assyrian days—well, perhaps

we had better not attempt to picture *that*! The mere addition of a simple, strut-like support between the free end of the 'neck' and the 'body' would have obviated this difficulty and rendered the instrument relatively efficient and unyielding to varying tension. And yet, even in Western Europe, this seemingly obvious and invaluable addition did not appear, as far as I can ascertain, until about the seventh or eighth century A.D.; and even then it seems to have been added somewhat half-heartedly, and a very long time had yet to elapse before the fore-pillar became an integral part of the framework and was allotted its due proportion in the general design.

I have purposely selected this particular series for my illustration, not because it is something new—indeed, it is already more or less familiar, and may be has even some merit in its lack of newness, since, in accordance with a popular dictum, it may urge a greater claim to be regarded as true—nor because it is specially striking, but rather for the reason that it illustrates suitably several of the points upon which I wish briefly to touch. Even in the severely condensed form in which I have been obliged to present this series of developments from bow to harp, there is, I think, demonstrated the practical application of several of the general principles upon which is based the theory whereby Colonel Lane Fox sought to elucidate the phenomena of human progress.

A series of this kind serves, in the first place, to demonstrate that the absence of historical and archæological evidence of the *actual* continuity in development from simple to complex does not preclude investigations into the early history of any product of human ingenuity, nor prevent the formation of a suggestive and plausible if largely hypothetical series, illustrating the probable chain of sequences along which some highly specialized form may be traced back link by link to its rudimentary prototypes, or even to its absolute origin, which in this particular instance is the ordinary shooting bow *temporarily* converted into a musical instrument. Where an actual chronological series is not forthcoming, a comparative study of such types as are available, even though they be *modern* examples, reveals the fact that, if classified according to their apparent morphological affinities, these types show a tendency to fall into line, the gap between the extreme forms—that is, the most simple and the most advanced—being filled by a succession of intermediate forms, more or less completely linked together, according to the number of varieties at our disposal. We are thus, at any rate, in possession of *a* sequence series. Is it unreasonable for us to conclude that this reflects, in great measure, *the* actual chronological sequence of variations through which in past times the evolutionary history of the instrument was effected from the earliest rudimentary form?

It is difficult to account at all for the existence of many of the forms such as I have briefly described, except on the supposition that they are *survivals* from more or less *early stages* in a series of progressive evolution; and, for myself, I do not believe that so inefficient and yet so elaborate an instrument as, to take an example, the harp of ancient Egypt, Assyria, and India could have come into being by any sudden inventive process, by 'spontaneous generation,' as it were, to use a biological term; whereas, the innate conservatism of the human species, which is most manifest among the lower and more primitive races (I use the term conservatism, I need hardly say, in a non-political sense) amply accounts for such forms having been arrived at, since the rigid adherence to traditional types is a prevailing characteristic of human culture, and only admits of improvement by very slight and gradual variations upon existing forms. The difficulty experienced by man in a primitive condition of culture of emancipating himself from the ideas which have been handed down to him, except by a very gradual and lengthy process, causes him to exert somewhat blindly his efforts in the direction of progress and often prevents his seeing very obvious improvements, even when they are seemingly forced upon his notice. For instance, the early Egyptian, Assyrian, and Greek harps, as I have already stated, were destitute of a fore-pillar, and this remained the case for centuries, in spite of their actually existing in an environment of other instruments, such as the lyre and *trigonon*, which in their rigid, unyielding frames possessed and even paraded the very feature which

was so essential to the harp, to enable it to become a really efficient instrument. The same juxtaposition of similar types, without mutual influence, may be seen in modern Africa among ruder forms of these instruments.

And yet, in spite of instances such as this—where a valuable feature suggested by one instrument has not been adopted for the improvement of another, even though the two forms are in constant use side by side—we must recognise that progress in the main is effected by a process of bringing the experience gained in one direction to bear upon the results arrived at in another. This process of grafting one idea upon another, or, as we may call it, the hybridization of ideas and experience, is a factor in the advancement of culture whose influence cannot be overestimated. It is, in fact, the main secret of progress. In the animal world hybridization is liable to produce *sterile* offspring; in the world of ideas its results are usually far different. A fresh stimulus is imparted, which may last through generations of fruitful descendants. The *rate* at which progress is effected increases steadily with the growth of experience, whereby the number of ideas which my act and react upon one another is augmented.

It follows, as a corollary, that he who would trace out the phylogenetic history of any product of human industry will speedily discover that, if he aims at doing so *in detail*, he must be prepared for disappointments. The tangle is too involved to be completely unravelled. The sequence, strictly speaking, is not in the form of a simple chain, but rather in that of a highly complex *system* of chains. The time-honoured simile afforded by a river perhaps supplies the truest comparison. The course of the *main stream* of our evolution series may be fairly clear to us, even as far as to its principal source; we may even explore and study the general effect produced by the more important tributaries; but to investigate in detail the contributions afforded in present and past of the innumerable smaller streams, brooks, and runlets is clearly beyond anyone's power, even supposing that the greater number had not changed their course at times, and even, in many cases, run dry. While we readily admit that important effects have been produced by these numberless tributary influences, both on the course and on the volume of the river, it is clear that we must in general be content to follow the main stream. A careful study of the series of musical instruments, of which I gave but a scanty outline, reveals very clearly that numberless ideas borrowed from outside sources have been requisitioned and have affected the course of development. In some cases one can see fairly clearly whence these ideas were derived, and even trace back in part their own phylogenetic history; but a complete analysis must of necessity remain beyond our powers and even our hopes.

It will have been observed that, in the example of a sequence series which I have given, the early developmental stages are illustrated entirely by instruments belonging to *modern savage races.* It was a fundamental principle in the general theory of Colonel Lane Fox that in the arts and customs of the still living savage and barbaric peoples there are reflected to a considerable extent the various strata of human culture in the past, and that it is possible to reconstruct in some degree the life and industries of Man in prehistoric times by a study of existing races in corresponding stages of civilisation. His insistence upon the importance of bringing together and comparing the archæological and ethnological material, in order that each might serve to throw light upon the other, has proved of value to both sciences. Himself a brilliant and far-seeing archæologist as well as ethnologist, he was eminently capable of forming a conclusion upon this point, and he urged this view very strongly.

The Earth, as we know, is peopled with races of the most heterogeneous description, races in all stages of culture. Colonel Lane Fox argued that, making due allowance for possible instances of degradation from a higher condition, this heterogeneity could readily be explained by assuming that, while the progress of some races has received relatively little check, the culture development of other races has been retarded to a greater or less extent, and that we may see represented conditions of at least partially arrested development. In other words, he considered that in the various manifestations of culture among the less civilized peoples were to be seen more or less direct *survivals* from the earlier stages or

strata of human evolution; vestiges of ancient conditions which have fallen out at different points and have been left behind in the general march of progress.

Taken together, the various living races of Man seem almost to form a kind of living genealogical tree, as it were, and it is as an epiphyte upon this tree that the comparative ethnologist largely thrives; while to the archæologist it may also prove a tree of knowledge the fruit of which may be eaten with benefit rather than risk.

This certainly seems to be a legitimate assumption in a general way; but there are numerous factors which should be borne in mind when we endeavour to elucidate the past by means of the present. If the various gradations of culture exhibited by the condition of living races—the savage, semi-civilized, or barbaric, and the civilized races—could be regarded as accurately typifying the successive stages through which the higher forms of culture have been evolved in the course of the ages; if, in fact, the different modern races of mankind might be accepted as so many sections of the human race whose intellectual development has been arrested or retarded at various definite stages in the general progression, then we should have, to all intents and purposes, our genealogical tree in a very perfect state, and by its means we could reconstruct the past and study with ease the steady growth of culture and handicrafts from the earliest simple germs, reflecting the mental condition of primæval man up to the highest manifestations of the most cultured races.

These ideal conditions are, however, far from being realised. Intellectual progress has not advanced along a single line, but, in its development, it has branched off in various directions, in accordance with varying environment; and the tracing of lines of connection between different forms of culture, as is the case with the physical variations, is a matter of intricate complexity. Migrations with the attendant climatic changes, change of food, and, in fact, of general environment, to say nothing of the crossing of different stocks, transmission of ideas from one people to another, and other factors, all tend to increase the tangle.

Although in certain instances savage tribes or races show obvious signs of having *degenerated* to some extent from conditions of a higher culturedom, this cannot be regarded as the general rule, and we must always bear in mind the seemingly paradoxical truth that degradation in the culture of the lower races is often, if not usually, the direct result of contact with peoples in a far higher state of civilization.

There can, I think, be little doubt that Colonel Lane Fox was well justified in urging the view that most savage races are in large measure strictly *primitive*, survivals from early conditions, the development of their ideas having from various causes remained practically stationary during a very considerable period of time. In the lower, though not degenerate, races signs of this are not wanting, and while few, possibly none, can be said to be absolutely in a condition of arrested development, their normal progress is at a slow, in most cases at a *very* slow, rate.

Perhaps the best example of a truly primitive race existing in recent times, of which we have any knowledge, was afforded by the native inhabitants of Tasmania. This race was still existing fifty years ago, and a few pure-blooded survivors remained as late as about the year 1870, when the race became extinct, the benign civilizing influence of enlightened Europeans having wiped this extremely interesting people off the face of the earth. The Australians, whom Colonel Lane Fox referred to as being 'the lowest amongst the existing races of the world of whom we have any accurate knowledge,' are very far in advance of the Tasmanians, whose lowly state of culture conformed thoroughly with the characteristics of a truly primitive race, a survival not only from the Stone Age in general, but from almost the earliest beginnings of the Stone Age. The difference between the culture of the Tasmanians and that of the Australians was far greater than that which exists between man of the 'River Drift' period and his Neolithic successors. The objects of every-day use were but slight modifications of forms suggested by Nature, involving the exercise of merely the simplest mental processes. The stone implements were of the rudest manufacture, far inferior in workmanship to those made by Palæolithic man; they were never ground or polished, never even fitted

with handles, but were merely grasped in the hand. The *varieties* of implements were very *few in number*, each, no doubt, serving a number of purposes, the function varying with the requirements of the moment. They had no bows or other appliances for accelerating the flight of missiles, no pottery, no permanent dwellings; nor is there any evidence of a previous knowledge of such products of higher culture. They seem to represent a race which was isolated very early from contact with higher races; in fact, before they had developed more than the merest rudiments of culture—a race continuing to live under the most primitive conditions, from which they were never destined to emerge.

Between the Tasmanians, representing in their very low culture the one extreme, and the most civilised peoples at the other extreme, lie races exhibiting in a general way intermediate conditions of advancement or retardation. If we are justified, as I think we are, in regarding the various grades of culture observable among the more lowly of the still existing races of man as representing to a considerable extent those vanished cultures which in their succession formed the different stages by which civilization emerged gradually from a low state, it surely becomes a very important duty for us to study with energy these living illustrations of early human history in order that the archæological record may be supplemented and rendered more complete. The material for this study is vanishing so fast with the spread of civilization that opportunities lost now will never be regained, and already even it is practically impossible to find native tribes which are wholly uncontaminated with the products, good or bad, of higher cultures.

The arts of living races help to elucidate what is obscure in those of prehistoric times by the process of reasoning from the known to the unknown. It is the work of the zoologist which enables the palæontologist to reconstruct the forms of extinct animals from such fragmentary remains as have been preserved, and it is largely from the results of a comparative study of living forms and their habitats that he is able, in his descriptions, to equip the reconstructed types of a past fauna with environments suited to their structure, and to render more complete the picture of their mode of life.

In like manner, the work of the ethnologist can throw light upon the researches of the archæologist: through it broken sequences may be repaired, at least suggestively, and the interpretation of the true nature and use of objects of antiquity may frequently be rendered more sure. Colonel Lane Fox strongly advocated the application of the reasoning methods of biology to the study of the origin, phylogeny, and etionomics of the arts of mankind, and his own collection demonstrated that the products of human intelligence can conveniently be classified into families, genera, species, and varieties, and *must* be so grouped if their affinities and development are to be investigated.

It must not be supposed—although some people, through misapprehension of his methods, jumped at this erroneous conclusion—that he was unaware of the danger of possibly mistaking mere accidental resemblances for morphological affinities, and that he assumed that *because* two objects, perhaps from widely separated regions, appeared more or less identical in form, and possibly in use, they were necessarily to be considered as members of one phylogenetic group. On the contrary, in the grouping of his specimens according to their form and function, he was anxious to assist as far as possible in throwing light upon the question of the monogenesis or polygenesis of certain arts and appliances, and to discover whether they are exotic or indigenous in the regions in which they are now found, and, in fact, to distinguish between mere analogies and true homologies. If we accept the theory of the monogenesis of the human race, as most of us undoubtedly do, we must be prepared to admit that there prevails a condition of unity in the tendencies of the human mind to respond in a similar manner to similar stimuli. Like conditions beget like results; and thus instances of independent invention of similar objects are liable to arise. For this very reason, however, the arts and customs belonging to even widely separated peoples may, though apparently unrelated, help to elucidate some of the points in each other's history which remain obscure through lack of the evidence required to establish *local* continuity.

I think, moreover, that it will generally be allowed that cases of 'independent

invention' of similar forms should be considered to have established their claim to be regarded as such only after exhaustive inquiry has been made into the possibilities of the resemblances being due to actual relationship. There is the alternative method of assuming that, because two like objects are widely separated geographically, and because a line of connection is not immediately obvious, therefore the resemblance existing between them is fortuitous, or merely the natural result of similar forms having been produced to meet similar needs. Premature conclusions in matters of this kind, though temptingly easy to form, are not in the true scientific spirit, and act as a check upon careful research, which, by investigating the case in its various possible aspects, is able either to prove or disprove what otherwise would be merely a hasty assumption. The association of similar forms into the same series has therefore a double significance. On the one hand, the sequence of related forms is brought out, and their geographical distribution illustrated, throwing light, not only upon the evolution of types, but also upon the interchange of ideas by transference from one people to another, and even upon the migration of races. On the other hand, instances in which two or more peoples have arrived independently at similar results are brought prominently forward, not merely as interesting coincidences, but also as evidence pointing to the phylogenetic unity of the human species, as exemplified by the tendency of human intelligence to evolve independently identical ideas where the conditions are themselves identical. Polygenesis in his inventions may probably be regarded as testimony in favour of the monogenesis of Man.

I have endeavoured in this Address to dwell upon some of the main principles laid down by Colonel Lane Fox as a result of his special researches in the field of Ethnology, and my object has been twofold. First, to bear witness to the very great importance of his contribution to the scientific study of the arts of mankind and the development of culture in general, and to remind students of Anthropology of the debt which we owe to him, not only for the results of his very able investigations, but also for the stimulus which he imparted to research in some of the branches of this comprehensive science. Secondly, my object has been to reply to some criticisms offered in regard to points in the system of classification adopted in arranging his ethnographical collection. And, since such criticisms as have reached me have appeared to me to be founded mainly upon misinterpretation of this system, I have thought that I could meet them best by some sort of restatement of the principles involved.

It would be unreasonable to expect that his work should hold good in all details. The early illustrations of his theories were to be regarded as tentative rather than dogmatic, and in later life he recognised that many modifications in matters of detail were rendered necessary by new facts which had since come to light. The crystallization of solid facts out of a matrix which is necessarily partially volatile is a process requiring time. These minor errors and the fact of our not agreeing with all his details in no way invalidate the general principles which he urged, and we need but cast a cursory glance over recent ethnological literature to see how widely accepted these general principles are, and how they have formed the basis of, and furnished the inspiration for, a vast mass of research by ethnologists of all nations.

It appears more than probable that Cambridge will be much involved in the future advancement of anthropological studies in Great Britain, if we may judge from the evident signs of a growing interest in the science, not the least of which is the recent establishment of a Board of Anthropological Studies, an important development upon which we may well congratulate the University. Within my own experience there have been many proofs of the existence in Cambridge of a keen sympathy with the principles of ethnological inquiry developed by Colonel Lane Fox, and I feel that, as regards my choice of a theme for the main topic of my address, no apology is needed. For my handling of this theme, on the other hand, I fear it must be otherwise. I would gladly have done fuller justice to the work of Colonel Lane Fox, but, while I claim to be among the keenest of his disciples, I must confess to being but an indifferent apostle.

I have been obliged, moreover, to pass over many interesting features in the

work of this ingenious and versatile scientist. I have made no attempt to touch upon his archæological researches, since it has been necessary for me to restrict myself to a portion only of his scientific work. In this field, as in his ethnological work, his keen insight, ingenuity, and versatility were manifested, while the close attention which he bestowed upon matters of minute detail have rendered classical his work as a field archæologist. While the greater part of his ethnological work is associated with the name Lane Fox, by which he was known until 1880, most of his researches into the remains of prehistoric times were conducted after he had in that year assumed the name of Pitt-Rivers, on inheriting an important estate which, by the happiest of coincidences, included within its boundaries a considerable number of prehistoric sites of the highest importance. That he made full use of his opportunities is amply manifested in his published works. In his archæological work are repeated the characteristics of his ethnological researches, and one may with confidence say of his contributions to both fields of inquiry that, if he advanced science greatly through his results he furthered its progress even more through his methods. By his actual achievements as a researcher he pushed forward the base of operations; by his carefully-thought-out systems for directing research he developed a sound strategical policy upon which to base further organised attacks upon the Unknown.

The following Papers were read:—

1. *The Evolution of the Lotus Ornament. By* Professor Oscar Montelius.

In *Egypt* the lotus has been represented from the earliest times as a real flower, often together with buds and leaves, or as an ornamental pattern. The lotus is drawn as well in the realistic form as in a conventional shape. The flower, figured in the more realistic way, shows numerous petals, which are pointed. The petals in the conventional flowers are rounded; often the number of the petals (sepals) is only three. The lotus is often combined with spirals. This occurs especially in the eighteenth dynasty. Not rarely two or more conventionally drawn flowers are placed one upon the other. Many Egyptian ornaments are formed by alternating natural and conventional lotus-flowers or by alternating lotus-flowers and lotus-buds.

In *Assyria*, where the lotus-ornaments are later than in Egypt, we find also both the realistic and the conventional lotus. The latter is generally called 'palmette.' In Assyria, as in Persia, the ornaments are often formed by alternating realistic and conventional lotus-flowers or by alternating lotus-flowers and lotus-buds.

Similar ornaments are also common in *Cyprus* and on the isles off the western coast of Asia Minor. In Cyprus, as in Phœnicia, the conventional lotus often has a peculiar form ('the Phœnician' or 'Cypriote palmette').

In *Greece* the lotus occurs already in the Mycenæan time, but it becomes common there only in the first millennium B.C. There, as in the Orient, we find the lotus in combination with spirals, the realistic and the conventional lotus alternating ('lotus and palmette'), as well as the lotus-flower in alternation with the lotus-bud.

Many capitals of Egyptian columns have the shape of a lotus-flower. Similar capitals occur also in Asia Minor, where they gradually get the form known as the 'Ionian capital.'

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2. *Note on the Entomology of Scarabs.*
By Professor W. M. Flinders Petrie, *D.C.L., LL.D., F.R.S.*

3. *Excavations at Ehnasya, in Egypt, with special reference to a Series of Roman Lamps.* *By* Professor W. M. Flinders Petrie, *D.C.L., LL.D., F.R.S.*[1]

4. *Recent Explorations at Great Zimbabwe.* *By* R. N. Hall.

The writer has just completed, on behalf of the Chartered Company, over two years' exploration and preservation work at the ruins of the Great Zimbabwe. The ruins' area is now shown to be more than three times larger than has hitherto been stated; many of the minor ruins, and also reconstructions of and additions to the older ruins, have been ascertained to be of no great antiquity, some dating most probably only from the thirteenth or fourteenth century of this era, and others are even more recent. It is now believed, on several obvious grounds, that the eastern half of the Elliptical Temple, and that which contains the best built and most massive walls, and also the sacred cone or 'high place,' is the oldest structure at Zimbabwe, while the western portion is surrounded by a wall of later and poorer and altogether slighter construction, probably also of the thirteenth century, or somewhat later, which wall took the place of a more substantial wall with a wider sweep outwards towards the west. The eastern has yielded to every explorer phalli in abundance, the author's discoveries bringing the ascertained number of true phalli found there to considerably over a hundred, together with carved beams and the older class of relic; while in the western half of the building not a single relic with any claim to antiquity has yet been found, the most remote period of any relic discovered here being considered by Dr. Wallace Budge, Keeper of Egyptian and Assyrian Antiquities at the British Museum, and other experts, to date from the thirteenth and fourteenth centuries of this era. Moreover, excavation has now for the first time shown the imperfect joint between the older and later walls. No ancient sign-writing has been discovered, but old post-Koranic writing on pottery was found in some minor ruins now known to have been occupied by Arab colonists. Important entrances and passages have been unburied, cement floors exposed, and gold in various forms discovered. The hills and valleys for some miles round Zimbabwe have been systematically searched for ancient or mediæval burying places without success, but from traces of walls and other possible signs in some of the more secluded valleys further searches may locate them. The history of the local native race of Makalanga, 'People of the Sun,' has now been ascertained for a period of at least two hundred years, as also an account of the native occupation of the ruins for a considerable number of generations past. Altogether the recent work, for which full credit should be given to the British South Africa Company, brings the mystery of these ruins much nearer solution, and it is confidently anticipated that when the full statement of the results of the recent examination has been considered by experts it will be possible to speak more definitely as to the original builders of these imposing and massive ruins.

FRIDAY, AUGUST 19.

The following Report and Papers were read:—

1. *Report on Anthropometric Investigation in Great Britain and Ireland.*—See Reports, p. 330.

2. *The Alleged Physical Deterioration of the People.* *By* Professor D. J. Cunningham, *M.D., F.R.S.*

[1] Summary in *Man*, 1904, 77.

3. *A Comparison of the Physical Characters of Hospital Patients with those of Healthy Individuals from the same Areas, with Suggestions as to the Influence of Selection by Disease on the Constitution of City Populations.* By F. C. SHRUBSALL, *M.D.*

I. *Distribution of Physical Characters among Hospital Patients.*

Certain physical features are found in greater frequency among hospital patients suffering from specified diseases than among the general populace of the areas from which the patients are drawn.

Stature.—Adult sufferers from tonsillitis, acute rheumatism and its sequelæ, such as heart disease, present a higher average stature, while sufferers from tuberculosis, nervous and malignant diseases, present a lower average stature than the healthy individuals also observed.

Cephalic Index.—No appreciable difference in London between hospital patients and the general population; but in Switzerland and South Germany the proportion of broad-headed individuals appeared to be rather greater among the inmates of the Volks-sanatoria for tuberculosis than among the healthy population.

Pigmentation.—Blond traits appear with greater frequency among sufferers from disorders of a 'rheumatic' nature, such as tonsillitis, acute rheumatism, and heart disease, than among the general populace. Brunet traits predominate among patients with pulmonary tuberculosis, nervous disorders, particularly epilepsy, and cancer. The remaining disorders showed no very special selection.

These results have been found to hold, not only in London, but also in Inverness, York, Shrewsbury, Newbury, Southampton, Dorchester, Chard, Paignton, and Wadebridge; and though the numbers investigated in these latter places were very small, the results all pointed in the same direction. Full details will be found in the 'St. Bartholomew's Hospital Reports,' vol. xxxix. Further confirmatory evidence as regards tuberculosis has been obtained from the public and private sanatoria at Davos and in the Black Forest.

A study of the distribution of mortality in different countries shows in broad lines some correspondence between the prevalence of fatal cases of disease and the physical type of the populations.

A study of the results of treatment of patients during the last two years at the Brompton Hospital shows that, as regards pulmonary tuberculosis, patients of the blond type respond slightly better than brunets, while for heart diseases the positions are reversed. The numbers available, some 1,500 in all, are, however, so far, too small to enable any very decided opinion to be formed.

II. *Distribution of Physical Characters according to Length of Residence in London.*

The classification adopted is that introduced by Ammon:—

Urban.—When two more generations have resided in London.

Semi-urban.—When the parents were immigrants from the country, but the individual observed was born in London.

Semi-rural.—When the individual was born in the country but lived most of his life in London.

Rural.—When the individual was born and always lived in the country.

Observations have been taken in hospital patients and controlled for the same class by observation made on their friends on visiting days.

It was found that *stature* shows a progressive diminution in successive generations of city life, both among patients and visitors. Similarly in *pigmentation* brunet traits showed (*a*) among the visitors a steady increase with each successive generation, passing from rural to urban, while (*b*) the distribution among the patients was irregular, the greatest proportion of blond traits occurring among the semi-rural class. This suggests that the blond elements feel more acutely the change in their environment, and that those born in the country are relatively less

resistant to the evil influences of a city life than those of the next generation born and bred amidst urban surroundings.

A comparison of the relative proportions of the different classes of Londoners among the general populace, as shown by the census, and among hospital patients, shows an increase of morbidity with increasing length of city residence.

III. *Distribution of Pigmentation in Children among the General Population of London and among Hospital Patients.*

It is found that in all parts of London the children are much fairer than the adults, and that the children attending the *medical* casualty rooms of the various hospitals are much fairer than those, presumably healthy, observed at school or in the streets in the sphere of attraction of each hospital; while the average of the general child population and of those attending accident-receiving rooms of the hospital is practically identical.

Hence it may be concluded that disease during childhood falls more heavily on the fair element. It would also appear that in the different districts of London the difference between the pigmentation of children and adults and the degree of infant mortality vary in the same direction, if allowance be made for the presence, in certain areas, of a large alien population.

So far, then, it would appear—

i. That certain diseases show special affinities for certain types of the population.

ii. That adult hospital patients, as a whole, are slightly fairer than the population in the sphere of attraction of each hospital.

iii. That among adults immigrating from the country the fair element sends an undue proportion of its members to the hospitals.

iv. That child patients are markedly fairer than the children in the districts around the hospitals.

v. That there are some indications of a relation between the difference in pigmentation of adults and children in any area and the degree of mortality in childhood of such an area.

IV. *Possible Influences of the above Factors in Changing the Distribution of Physical Characters in Successive Generations.*

In the earliest years of life the fair element is certainly at its maximum. During the first ten years of life the chief causes of death are disorders of the alimentary and respiratory systems, coming on either directly or as sequelæ of some of the infectious disorders common in childhood. These, as we have seen, even in adult life, show (as far as case incidence is concerned) a certain degree of greater frequency among the fairer class of the community. The diseases associated with brunet traits are at this period at their minimum. The quinquennial period 10-15 is characterised by a very low mortality, which seems very evenly spread over the different disorders, but falling least on the 'brunet' group.

The special incidence of illness and probably of mortality on the lighter class of the community continues until the period 20–25, when, owing to the sudden rise both of case incidence and mortality from pulmonary tuberculosis, the darker element begins to suffer severely. During this period, 20–25, it seems certain that the darker individuals are at their maximum degree of frequency among the general population. This age, however, is that at which most marriages occur, so that assuming that the marriage rate is uniform among the different types—which is, however, susceptible of proof—the parents of the next generation should have maximum of pigmentation. Supposing the difference to be slight, yet it might in time produce the effects now everywhere visible of a greater pigmentation in urban areas. Tables show that most marriages occur between 21 and 25, next in frequency between 25 and 30, and the majority of offspring are born in the early years of married life.

However, as will be seen from any diagram of death-rates between 20 and 40,

the chief cause of death at this period of life is pulmonary tuberculosis, which both in case-incidence and death-rate draws most heavily from those of brunet traits, so that as the time passes on the relative frequency of darker individuals is diminished, and the parents of children born later in life are less likely to present the same relative preponderance of brunet traits. However, it is also true that fewer children are born of late than early marriages, so that this would not quite equalise matters. We have seen that the most overcrowded areas are, on the whole, the most brunet areas, and also those in which the infant mortality is greatest. That they do not become still more brunet is, perhaps, to be explained by the earlier rise of mortality from pulmonary tuberculosis, the greatest scourge during the child-bearing periods of life.

The remaining brunet-selection diseases, those of the nervous systems and cancer, presenting their maximum later in life, only slightly affect the population during this important period, and their influence must be slight.

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4. *An Anthropometric Survey: its Utility to Science and to the State.*[1] *By* JOHN GRAY, *B.Sc.*

The principal object of an Anthropometric Survey is to make maps showing the distribution of physical and other measurable characters of the population of a country. Topographical and geological surveys have already been carried out in great detail by most civilised States, but only a few countries have made more or less feeble attempts to map out the characteristics of their populations with the same precision as they have mapped out their topographical features and their geological strata.

It may be objected that an anthropometric survey would be impracticable and useless because there is not the same permanence in the physique of a people that we find in the topography and in the geological strata. But we know enough of the law of ancestral heredity to be practically certain that the average bodily dimensions of a stationary population will be transmitted with little or no change from one generation to another for vast periods of time, provided the environment or conditions of life remain constant. For example, recent investigations have shown that the physique of the present population of Egypt is practically identical with that of the population 9,000 or 10,000 years ago.

There is, therefore, no necessary lack of the permanency necessary to make a survey of the national physique possible. If the environment should not be constant, the stability of the physique would still be sufficient to enable surveys to be taken at intervals of five or ten years.

The Ideal Anthropometric Survey.

In an ideal anthropometric survey statistics would be collected of the complete bodily and mental features and activities of the population in every part of the country. The environment peculiar to each section of the population would also be noted. All characters observed should be capable of more or less precise measurement.

The dimensions of the body can now be measured with the greatest precision. Measurements of physiological activities, such as the acuteness, &c., of the senses, say of sight, hearing and smell, can also be measured with considerable accuracy. Psychological characters are more difficult to measure, but still a fair estimate of the mental characters of a local population may be formed from its occupations and amusements, and from the number of distinguished men it has produced.

The Practical Anthropometric Survey.

In a practical survey we must be content with the measurement of a few characters in order to keep the cost within moderate limits.

As a practical scheme that might be carried out by the State, I give, in out-

[1] To be published in full by the Anthropological Institute.

line, the scheme for a survey of the British Isles submitted to the Privy Council Committee on Physical Deterioration, by Professor Cunningham and myself.

According to this scheme the United Kingdom would be divided into 400 districts, in each of which a representative sample of about 1,000 adults of each sex would be measured. The whole of the school children would be measured because a thousand of each sex for each age interval of one year would be required, and this would amount to about the whole of the school population. The survey would be completed once every ten years, and the total number measured in that time would be about 800,000 adults and 8,000,000 children. The work, it has been estimated, could be carried out by a staff of twenty to thirty surveyors constantly employed. The employment of part-time surveyors, such as school teachers, on account of the cost of training the large number required would be very much more expensive than the employment of a small number of whole-time surveyors.

The following is the list of dimensions to be measured, drawn up by Professor Cunningham:—Stature, chest, weight, head (length, breadth, and height), breadth of shoulder, breadth of hips, vision, and degree of pigmentation.

Environment or conditions of life would also be noted, and much information as to environment could be obtained from statistics collected by other agencies.

A statistical department in connection with the survey would work out the averages for each district, the deviations from the average, draw frequency-curves, calculate correlations, and prepare maps.

Utility to Science.

The material thus collected and classified would add immensely to our knowledge of the distribution and origin of the races of our own country. The correlations that would be discovered between the different physical characters and between physical and mental characters would be new and valuable scientific discoveries. The correlations discovered between the physique of man and his environment would throw much light on the nature of evolution. It is impossible to anticipate all the developments that would result from so great an accession to our exact knowledge of man.

Utility to the State.

There has been much agitation recently in this country about physical deterioration. Whether this deterioration is really taking place or not cannot be settled by any anthropometric statistics at present in existence. A more or less probable guess can be made in a few cases. With an anthropometric survey in being the question could be answered in the positive or the negative with certainty. Moreover, by calculating correlations between physique and all probable influences the causes of the deterioration would be indicated.

The importance of such information to the statesman, to the sociologist, and to the public themselves hardly needs to be pointed out. Civilisation has brought so many new influences to bear upon the more advanced races of mankind that we are quite in the dark as to their ultimate effects. Influences may be at work which are steadily driving us by invisible steps on the road to national ruin. The anthropometric instrument would detect these insidious changes before they were visible to the naked eye; statesmen and the public would be warned in time, and the degeneration might be arrested before it was too late.

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5. *Discussion on Physical Deterioration and Anthropometric Survey.*

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6. *The Progress of the Ethnographic Survey of Madras.* *By* EDGAR THURSTON.

The author described the scope of the survey, and the method and cost of conducting it; the nature of the anthropometric and ethnographic evidence which is collected; the most important physical characters (stature, nasal, and cephalic

indices); the photographic record of racial types; the problem of combined museum collection and investigation; the difficulties encountered in carrying out the work of a Government official owing to the timidity and mistrust of the people, and their fears of increased taxation, plague-inoculation, and transportation.

The Madras survey covers the following *linguistic* areas:—Tamil, Telugu, Malayalam, Kanarese, Tulu, Khond; and the *racial* division into Pre-Dravidian or Archi-Dravidian, Aryo-Dravidian, Scytho-Dravidian. In distinguishing these the nasal index is of value as a guide to racial admixture.

The author describes the characteristics of the jungle tribes, short of stature and platyrrhine; criticises Gray's head-measurements of the Indian Coronation contingent; discusses the two main types which are found among the natives of Southern India; and gives the distribution of the dolicho-, mesati-, and sub-brachycephalic types; and an account of the type of head in the Kanarese area, and of Risley's Scytho-Dravidian hypothesis. Valuable evidence on these points is afforded by the deviation of cephalic length, breadth, and index in various castes and tribes, especially Brâhmans, Todas, Palayams, Pallis, and Urâlis.

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7. *Interim Report on the Present State of Anthropological Teaching.*

See Reports, p. 341.

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8. *Recent Anthropometric Work in Scotland.* *By* J. F. Tocher, *F.I.C.*

During the present year a survey of the inmates of Scottish asylums has been carried out by the author, the characters measured or noted being head-length, head-breadth, head-height (from centre of auricular orifice to vertex), stature, shape of nose, and colour of hair and eyes. This survey is due to the suggestion of Dr. John Macpherson, one of the Commissioners in Lunacy for Scotland, through whose good offices every facility was given by the medical superintendents and other authorities to make the necessary observations. The expenses of the survey were borne by a grant secured, at Dr. Macpherson's instance and that of his co-trustees, Sir Arthur Mitchell and Sir John Sibbald, from the Henderson Trust of Edinburgh. The actual data giving the records of the measurements will shortly be published by the Trust, and will be available to those interested, while the results of a complete analysis of the statistics with some observations thereon will appear in 'Biometrika.' Altogether 4,436 males and 3,951 females were measured.

The distributions of head-lengths, head-breadths, and head-heights are of Type IV. of Pearson's series. The means and standard deviations do not indicate any special differences from those of published results elsewhere. Since, however, the measurements are those of a rather selected sample of the general population, significant differences may be revealed on a closer examination of the data. Thirty correlation tables have been prepared, these including both measurable and non-measurable characters. An example of the first, that of head-length and head-breadth, gives the value of $r = \cdot 501$, probably about the highest found for this particular pair of characters. The correlation between hair and eyes of a sample of 1,200 was found to be ·402, compared with ·3795 for Aberdeenshire children. The physical characters of 1,000 school children (including 500 Glasgow children by Mr. R. Tocher) have also been noted. In addition to the ordinary measurements, the radius of curvature of the cornea and the visual acuity of the children were determined. The data obtained will supply additional information as to the rate of growth generally and of the relationships existing between the chief dimensions of the eye. An analysis of these measurements will also be published at an early date.

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9. *The Distribution and Variation of the Surnames in East Aberdeenshire in* 1696 *and* 1896. *By* J. F. TOCHER, *F.I.C.*

In a recent paper[1] some results were given of an analysis of the frequency of surnames occurring in East Aberdeenshire in 1896. The author has now made a complete analysis of the whole of the surnames occurring in the 'List of Pollable Persons within the Shire of Aberdeen' in 1696. This paper deals with the distribution found to exist in East Aberdeenshire at that time, and its relationship to that found in 1896. It was found that the two most common surnames of 1696 were still the most common two hundred years later, these being Smith and Milne. The surnames of four great county families, Gordon, Hay, Forbes, and Fraser, were frequent in 1696, but have now, with the exception of the Frasers, very few representatives in East Aberdeenshire. The number of surnames existing in the district in 1696 was found to be 841, as against 725[2] found in 1896. The total number, taking both periods, amounted to 1,121, of which 445 were common to both periods. Of the 841 in 1696, 396 have died out, while 280 new surnames appear in 1896. The form of the distribution of surnames with respect to the magnitude of the number of representatives possessed by each has been found to follow that of Type I. of the series deduced by Pearson[3] (general form $y=y_o\left(1+\frac{x}{a_1}\right)^{m_1}\left(1-\frac{x}{a_2}\right)^{m}$, the equation to the curve being $y = \cdot 6525\ x^{-\cdot 6046}(7-x)^{2\cdot 7976}$. If the surnames in the surrounding districts are taken into consideration in both the series, a curve of the same variety of Type I. results. It is evident from the results that, besides the disappearance of surnames from a district due to migration, the extinction of surnames is going on on a large scale. Such extinction is not due to any diminution in fertility, but to the laws governing fertility—to its chance nature in general. Galton and Watson[4] have considered this problem from a theoretical standpoint, and have shown that with an equal distribution of surnames a certain number would become extinct in each generation. The number of surnames having 1, 20, 40 . . . n representatives at the tenth generation have been successively calculated (using Galton and Watson's values of the constants) when a distribution similar to the observed one was obtained. From this it appears that any community adopting a different surname for each male would in the course of a few generations inevitably drift into a distribution similar to what has been shown to exist in East Aberdeenshire. The degree of association of the two series having an interval of 200 years between them has also been considered. It has been ascertained by Pearson's contingency method[5] that the deviation from independent probability is considerable, the value of ϕ^2 being found to be 1·57. The two series are therefore, as would be expected, distinctly correlated. The correlation existing between the commonly occurring surnames of both series amounted to ·5437, while that between the two complete series amounted to ·3924. Among the surnames common to both periods, 23 per cent. maintained the frequency of 1696 in 1896, while 40 per cent. were more frequent in 1896 than in 1696, and in 37 per cent. of the cases the surnames were less frequent at the end of two centuries. This gives, irrespective of whether it is due to emigration, immigration, or the laws governing fertility, an idea of the rate of change in the frequency of surnames, in a general way, in Aberdeenshire during the last 200 years.

[1] *Brit. Assoc. Report*, 1901, p. 799.

[2] 751 was the actual number given in 1896, but of those 26 were variants.

[3] 'On Skew Variation in Homogeneous Material,' *Roy. Soc.*, vol. clxxxvi., p. 381.

[4] *Natural Inheritance*, pp. 241–248.

[5] 'On the Theory of Contingency, &c.,' by Professor K. Pearson, *Drapers' Company Research Memoirs*, Biometric Series I., 1904.

MONDAY, AUGUST 22.

The following Papers and Report were read:—

1. *A Plan for a Uniform Scientific Record of the Languages of Savages. By* Sir RICHARD TEMPLE, *Bart., C.I.E.*

During the last thirty years the careful record of 'savage' languages has been frequently undertaken, and a serious difficulty has arisen owing to the accepted European system of grammar, which is based on a system originally evolved for the explanation of highly inflected languages only, whereas in many, if not in most, 'savage' languages inflection is absent or present only in a rudimentary form. The European system has therefore been found to be unsuited for that purpose. During attempts to provide a suitable system a theory of universal grammar was evolved.

The root idea is that, as speech is a convention devised by the human brain for intercommunication between human beings, there must be fundamental natural laws by which it is governed, however various the phenomena of those laws may be.

The theory starts with a consideration of the sentence, *i.e.*, the expression of a complete meaning, as the unit of all speech, and then seeks to discover the natural laws of speech by a consideration of the internal and external development of the sentence.

In explaining internal development the sentence is ultimately divided into words, considered as components of its natural main divisions, in the light of their respective functions. This leads logically to a clear definition of grammatical terms.

From the consideration of the functions of words the theory passes to that of the methods by which they are made to fulfil their functions. It shows how words can be divided into classes according to function and explains their transfer from class to class. This leads to an explanation of connected words and shows how the forms of words grow out of their functions. The growth of the forms is next considered, involving an explanation of roots, stems, and radical and functional affixes. This explanation shows that the affixes determine the forms of words. This is followed by a consideration of the methods by which the affixes affect the forms.

The sentence, *i.e.*, the unit of speech, is then considered as being itself a component of something greater, *i.e.*, of a language. This consideration of its external development leads to the explanation of syntactical and formative languages, the two great divisions into which all languages naturally fall—*i.e.*, those which depend on the position of the words, and those which depend on the forms of the words, in a sentence to express complete meaning.

Syntactical languages are then shown to divide themselves into analytical, or those which depend for comprehension mainly on the position of the words, and into tonic, or those which combine tone with position for the same purpose. So also formative languages are shown to divide themselves into agglutinative and synthetic, according as the affixes are attached without or with alteration. Formative languages are further divided into premutative, intromutative, or postmutative, according to the position of the affixes.

The theory further explains that, owing to a fundamental law of Nature, no language can have ever been left to develop itself alone, and how this leads to the phenomenon of connected languages, and thus to groups and families of languages. It also explains how—again according to a law of Nature—no language has ever developed in one direction only or without subjection to outside influences, leading to the natural explanation of the genius, or peculiar constitution, that each language possesses.

It is believed that every language must conform to some part or other of the theory, and it can be shown that children and untutored adults in learning a language act on the instinctive assumption of the existence of such a theory.

Assuming the theory to exist and to be correctly stated, it is of great practical importance as leading to the quick, accurate, and thorough, because natural, acquirement of a new language.

In brief, the theory is based on the one phenomenon which must of necessity be constant in every variety of speech—viz., the expression of a complete meaning, or, technically, the sentence. Words are then described as components of the sentence, first, as to the functions performed by them, and next as to the means whereby they fulfil their functions. Lastly, languages are considered according to their methods of composing sentences and words.

Phonology and orthography—*i.e.*, pronunciation, spelling, and alphabets—are not considered, as these belong to other branches of the development of the human mind.

The theory has been already applied—and, it is claimed, successfully—to sixteen languages, including English, Latin, and Hungarian, selected for the purpose as being illustrations of every type and every kind of development.

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2. *On Group-Marriage in Australian Tribes. By* A. W. Howitt.

The native tribes which surround Lake Eyre, in Central Australia, have two forms of marriage. One follows upon betrothal of children by their mothers, and the other is the subsequent marriage of the woman to a younger brother of her husband. On ceremonial occasions this latter form of marriage is extended in the tribe by the allotment to each other of men and women who are already allotted to each other under one or other of the two marriages.

This group-marriage also occurs in other tribes in South-east Australia, either in the form which it has in the Lake Eyre tribes or as a survival of custom. It is also shown by the system of relationship in the Australian tribes to have been at one time common to all.

In the Lake Eyre tribes there is female descent with group-marriage. In other tribes in which group-marriage is merely a survival, or is merely indicated by the terminology of relationship, there has been more or less an approach to a form of individual marriage accompanied by a change from female to male descent.

Changes such as these are attended also by alteration of the social organisation of the tribes. In one direction there has been a segmentation of the tribe from a division of two intermarrying exogamous moieties of the tribal community to four such divisions, and finally into eight, with a change also in the line of descent. In the other direction there has been a partial or complete loss of this division of the community into four and eight segments.

The tribe has become organised on a geographical basis into a number of local groups, and these localities have become exogamous and intermarrying. In these changes in the organisation of the tribes the line of descent has passed from the female to the male line.

In the Lake Eyre tribes a group of totems is attached to each exogamous moiety. These remain in existence in the segmentation into four and eight groups.

In those tribes where the organisation of the tribe has become local, the totem groups have either become more or less extinct or have changed in extreme cases into magial names without influence in marriage.

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3. *The Passing of the Matriarchate. By* R. S. Lepper, *M.A., LL.M.*

General idea of the matriarchate as contrasted with the patriarchate and the modern family. Polyandry. The matriarchal country of S. India: its former wide and present narrow extent. The matriarchate as a stage of civilisation: the rule or the exception? Malabar only exceptional in its fertility and seclusion. The geographical features of the Malabar coast strip: its heavy rainfall, alluvial soil,

fertility. Population kept down by Nature; life short but easy. The Indian matriarchal state. Its chief racial (caste) divisions: the great horizontal division into caste and casteless; the great vertical cross-division into east-coast men and west-coast men, or patriarchalists and matriarchalists. Extremely primitive religious, social, and marital relationships among the indigenous population.

Effects of early immigration of Aryan patriarchalists. The matriarchate as a working social system. (*a*) Advantages: Leads to love marriages, terminable at pleasure, and leaving the mother the custody of the children; facilitates natural selection; secures the liberty of woman. (*b*) Disadvantages: Desertion of wife. The system conflicts with the natural affection of father for child, and the desire to provide for wife and children independent of the matriarchal clan. Position of the wife on the death of the husband. Impoverished clans.

Effect of progress on the matriarchate. Helpless position of wife and children on death of husband. Neglect by brother and headman of clanswomen and children, who become dependent on the father's gifts for their comforts, education, and start in life. Great difficulty in alienating or even developing the land of the clan owing to the necessity for getting the consent of every clansman. The matriarchate puts the husband in the position of tenant at will, never secure from eviction in favour of a successful rival. Nor is the wife ever sure of her husband's faithfulness. Consequent dislike of the system by both husband and wife in cases of true love marriages.

Effects of a further influx of patriarchal families. The Brahman patriarchalist contempt for matriarchalism. This disgusts the matriarchal man.

Tendency for the matriarchate to pass into the patriarchate when the latter is the highest system known as practicable, owing to the unsettled state of society. Advantages of the patriarchate. The matriarchate as a political form. Matriarchal monarchical succession: its nature and peculiarities. The monarch's children cannot succeed; hence he cannot so well train his successor. Danger of splitting the nation into factions. Great difficulty which consequently confronts the ruler. Consolidation of matriarchal tribe states into matriarchal country states. Risk of a breach of administrative continuity on a change of the succession. Peculiar system of adoption. Dangers of regencies.

The progressive matriarchal state. The matriarchate and the education of women; the patriarchate and female ignorance. Rapid material and intellectual progress of Travancore and Cochin. The patriarchal-matriarchal feud. The matriarchalist as natural man. The outlook. Attempts to modify the matriarchate. Revolt against the matriarchate very marked during the last twenty-five years.

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4. *An Anthropological View of the Origin of Tragedy.* *By* Professor W. Ridgeway, *M.A.*

In the case of Greek tragedy scholars were agreed until recently (1) that it originated in the worship of Dionysus; (2) that it was invented by the Dorians; (3) that the Satyric drama was invented by the same Dorians; (4) that the *thymele* was from the outset the altar of Dionysus.

All these propositions are either wholly or in part untrue.

(1) Dionysus was a newcomer in Greece. In Homer he is a Thracian deity, and his great Thracian sanctuary was his oracle among the Satræ, an aboriginal melanochroous tribe, of lax social habits. The Satyrs and Bacchæ are simply the young men and women of the Satræ in their native dress and behaviour. Similar orgies are practised by modern savages to ensure fertility and good crops, and similar rites are traceable in early Greece, *e.g.* the 'tragic dances' in honour of the pre-Achæan Adrastus at Sicyon (in the very region where the Dorians are said to have invented tragedy), which Herodotus (v. 67, when rightly interpreted) describes as being subsequently transferred to Dionysus by Cleisthenes. The dramatic celebration of the death of Scephrus at Tegea (Pausanias, viii. 53) and the ceremonies held to expiate the massacre of the Phocæans (Herodotus, i. 167)

point to the same conclusion, that the drama in Greece originated in the worship of the dead long before the cult of Dionysus spread from Thrace.

(2) The claim of the Dorians, though quoted by Aristotle ('Poetics,' 3), is not endorsed by him. The long *a* in the dialect of the Attic chorus-dialect is not necessarily Doric, as it existed also in old Attic and other dialects;[1] and as Dorians were not admitted to Athenian religious ceremonies (Herodotus, v. 72), it is difficult to see why their dialect should have been adopted in them. Arion, moreover, who invented the dithyramb (Herodotus, i. 23), was not a Dorian, but a Lesbian.

(3) The only really Dionysiac part of tragedy is the Satyric drama, which is of northern origin (*v.* above), and was appended to the old local ritual when the cult of Dionysus was superimposed on that of Adrastus or other local hero.

(4) The instances already quoted and the recitation of a hero's fate at his tomb (*e.g.*, in the *Choephoroi* of Æschylus) indicate that the *thymele* was originally the shrine or tomb of the local hero.

The development effected by Thespis consisted, not in the introduction of an actor into the ceremony or in the use of 'tragic dances' for moral purposes, but in the separation of what had hitherto been a piece of religious ritual from its local shrine, and the conversion of it into a distinct form of literary performance which could be enacted anywhere. It is in this sense that Thespis 'carried about his plays on wagons.' The analogy of mediæval drama is exact: originally a piece of religious ritual performed in church, and based on a particular set of incidents, it became detached both from locality and topic, and fell into the hands of 'strolling players.'

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5. *The So-called Tomb of Mena at Negadeh, in Upper Egypt.* *By* JOHN GARSTANG, *B.Litt.*

A special piece of work undertaken by the Beni Hasan Excavation Committee was the re-excavation of the royal tomb at Negadeh, which was discovered and opened some years ago by M. de Morgan, who has since published the results of his investigations.[2] This new examination was made during March of the present year, and the method adopted was to search through all the earth previously thrown out of the interior, as well as to clear and clean up the tomb structure itself. The plans and descriptions published by De Morgan, supplemented by Borchardt,[3] are faithful, and require no serious revision. Interest chiefly turns, therefore, to the objects newly found in the *débris* and in an undisturbed deposit within a niche inside the structure. All the pottery, which was mostly in fragments, was examined and specimens were collected. A great quantity of alabaster was found and brought away, together with fragments of obsidian, crystal, diorite, breccia, and other materials familiar in the archaic period. Many of these were found to fit, and in some cases complete, vases previously recovered, and are now placed in the museum at Cairo. The best objects of art are a fish and a cat, both carved in ivory, each about four inches in length, and a large pendant of crystal. About a hundred clay jar-sealings, some in good preservation, were found to be mostly duplicates of those published by De Morgan, with a few new examples which are difficult to read. These constitute a chief source of historical material for the period; but in addition there were found four ivory tablets, inscribed, and the portion of a fifth. These are as follows:

a. Small ivory tablet bearing name of *Narmer*, alternatively transcribed *Bezau* (broken).

b. Small ivory tablet with the name of *Neith-hetep* upon the reverse; obverse, he number 135 (complete).

[1] Ridgeway, *Early Age of Greece*, i. 67.
[2] *Le Tombeau Royal de Negadeh.*
[3] *Das Grab von Menes.*

c. Small ivory tablet of (?) *Baui* (sign of three birds not identified), with the number 1400 on the obverse (complete).

d. A fragment of the original tablet of Mena discovered by De Morgan. The new piece practically completes the whole, to which it has been joined in the museum of Cairo.

e. A smaller replica in ivory of the same tablet (*d*), which is wanting in the upper right corner the group which contains the MEN-sign, identified by some with Mena, but is complete and entire elsewhere, and thus enables the whole tablet to be restored.

The important historical facts learnt from this excavation are two:

i. The association of the names of Narmer, Neith-hetep, and Aha (possibly Mena).

ii. The archæological evidence that the tomb certainly belongs to the period of the beginning of the First Dynasty or the close of the pre-dynastic period. From the character of the objects found within it there is no reason to suppose that it is of a later or mixed date.

Summing up, the tomb belongs to the period of the traditional *Mena*, first king of Egypt. It contains chiefly the name of *Aha*, which is identified with a *Mena* from the tablet of De Morgan. In lack of rival claims, considering, too, the abundance of material for these times recovered by Petrie and others, it may be believed on present evidence that *Aha* was the *Mena* of tradition. This being so, if *Aha* was buried at Abydos, as suggested by Petrie's discoveries there, then it is probable that the tomb at Negadeh was that of *Neith-hetep*, whom circumstantial evidence points to as the queen-mother of Mena. The inscriptions bearing this name are particularly plentiful, and the objects dedicated to her of special quality.

The objects discovered in this excavation not retained by the Cairo Museum, excluding tablets *a, b, c, d*, but including *e*, have been presented by a member of the Committee to the Museum of Egyptian Archæology in the University of Liverpool. The tablets *a, b, c*, and the fish of ivory are in the MacGregor Collection.

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6. *On an Interment of the Early Iron Age found at Moredun, near Edinburgh. By* F. R. COLES *and* T. H. BRYCE, *M.D.*

The present example is the first completely attested instance of an interment associated with relics of the Early Iron Age in Scotland. It was discovered in August 1903 at Moredun, near Edinburgh. The remains were contained in a cist, 4 feet long by 2 feet 3 inches wide and 22 inches deep, covered by several flagstones of varying size.

The associated relics were a fibula of La Tène type, which showed a fragment of some loosely woven fabric in the catch; a ring brooch or buckle; and a circular open pin-head without ornamentation. The stem of the pin is bent at right angles to the head. Such objects are very rare in Scotland. Pins of this variety in iron and bronze have been found in brochs, in Forfar and Caithness, and in the refuse heap at a fort in Argyleshire. It must be considered earlier than another variety with flat head enamelled in colours with 'late Celtic' ornament. As it has been found associated with pieces of Samian ware and Roman denarii of the latter part of the second century A.D., and, further, as the fibula is a simple form from a late La Tène type widely diffused on the Continent at the end of the first century, the interment can scarcely be earlier than some time in the second century A.D. The osseous remains are those of two individuals placed in the doubled-up position, one above the other, with the heads to opposite ends of the cists, but faces in the same direction. One was a young adult, the other an adolescent of about twenty-one years of age. The sex, owing to the fragmentary state of the bones, could not be determined with certainty; probably both were female. The stature of the adult was about 5 feet 5½ inches. The following are such measurements

of the long bones as could be taken:—Humerus, 315 mm.; femur, 458 mm.; tibia, 363 mm. The platymeric index is 78·1; pilasteric, 98·4; the platycnemic, 77.

The skull was broken away on one side and imperfect on the other, but the sagittal section was complete. The transverse measurements have been calculated approximately:—

Maximum length	192
„ breadth	*a*144
Cephalic index	*a*75
Basi-bregmatic height	140
Height index	*a*72·8
Basi-nasal length	100
Basi-alveolar length	93
Gnathic index	93

The radii on the mesial surface are as follows:—Basion to occipital, 113 mm.; to lambda, 122 mm.; to mid-parietal point, 140 mm.; to bregma, 140 mm.; to mid-frontal point, 136 mm.; to glabella, 110 mm.; to nasion, 100 mm.; perpendicular, 138 mm.; distance from perpendicular to anterior pole, 80 mm.; to posterior pole of cranial cavity, 93 mm.

The face measurements could not be accurately taken, but the length-breadth index was doubtless lepto-prosopic.

The sutures were all patent, the set of teeth was complete, and the crowns showed no attrition. The chief characters are the very full rounded frontal region, the flatness of the vertex, the absence of sagittal ridge, and the rounding out of the sides.

A comparison with the skulls from this district, described by Sir William Turner,[1] shows that in general character it agrees with the majority of more modern examples; and though no general statement can be founded on a single specimen the probability is that the type now prevailing in Midlothian was already established when the interment took place.

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7. *On a Phase of Transition between the Chambered Cairns and Closed Cists in the South-west Corner of Scotland.* By T. H. Bryce, *M.D.*

If the rare instances of interment in cinerary urns be excluded, the forms of prehistoric sepulture in Argyleshire and Buteshire may be grouped under two heads: (1) Interment in chambers with a portal, but no passage, of entrance; and (2) interment in completely closed cists.

The two classes *agree* in one respect, that without any hint of difference of time relationships, within the respective classes, the interment may be either by inhumation or after cremation. They *differ* in the mode of interment, in the character of the osseous remains, and in their associated relics.[2] While the implements are invariably of stone in the chambers, they are occasionally of bronze in the closed cists; but the character of the pottery is a more discriminating feature. The chamber pottery is of a black paste. The vessels are round in the bottom, and have either a broad flat lip or are inclined inwards to the mouth; the decorative pattern is one of straight lines and dots, or of fluted markings, or (rarely) of concentric semi-ellipses. The closed cist pottery is of a red paste, generally of the 'food-vessel' type, but more rarely of the 'drinking-cup' or 'beaker' class.

Besides the chamber in its typical form an atypical form occurs, consisting of a single compartment covered by one flagstone (cistvaen), with one end lower than the others, and forming the sill of a portal guarded by two upright stones.

The exploration of a cairn at Glecknabae, in Bute, afforded a clue to the

[1] *Trans. Roy. Soc.*, Ed. xl., part iii., No. 24.
[2] Bryce, *Proc. Soc. Antiq. Scot.*, vols. xxxvi., xxxvii., xxxviii.

classification of the chambered structures and pointed to a stage of transition from the chamber to the short cist.

The cairn, which was large but mutilated, contained two small chambers and a short cist, and presented the further curious feature that it was placed on the top of a shell refuse heap of considerable extent.

Both chambers were of the atypical form, measuring 4 feet long by 3 feet wide, and 4 feet deep. They were placed radially to the edge of the cairn. The closed cist was 3 feet 3 inches by 2 feet 1 inch, and 2 feet deep.

The chambers both contained burnt bones, one the fragment of an unburnt skeleton, and the short cist an unburnt interment.

The chambers yielded flakes and a knife of flint, broken fragments of quartz pebbles, and flakes of pitchstone and pottery. This last provided the key to the period to which the chambers belonged, for in one a typical piece of chamber pottery was found, with fragments of a second; in the other, fragments of four vessels were recovered, of the 'beaker' or 'drinking-cup' class. The decoration was zonular in one, but irregular in the others.

The phenomena indicate a triple occupation of the site at three successive epochs. The presence of the 'beaker' type of ceramic seems to point to the small chamber being a *late* departure from the normal chamber structure.

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8. *The Cimaruta, a Neapolitan Charm.* *By* R. T. Günther, *M.A.*

A series of specimens and lantern-slides of this interesting compound charm was exhibited in order to draw attention to the manner in which it has become developed from a number of primitively independent emblems which have been grafted upon a silver representation of a sprig of rue. Notwithstanding the varied proportions and positions of the component parts, a certain uniformity of plan is always conspicuous, even in the most degenerate specimens; but in its modifications it is an excellent example of the working of the laws of evolution. Its efficacy as a charm would be impaired by too great a departure from the prototype, while the requirements of technique and of decorative art have produced series of interesting variations. Several vestigial and useless structures, which no doubt had some purpose once, have been retained.

To represent the structure of these complex charms the author has employed certain constitutional formulæ, in which the various emblems are represented by their initial letters, and brackets are used to denote the mutual relationships of the parts, as in the following examples:—

1. The charm, consisting of a lotus-flower (L) held in a fist (F), is represented

$$F(L).$$

2. The cimaruta, in which the three-branched rue-sprig supports a fist, a moon, a fist, a key and a fist, in order from left to right, is represented

$$R_3(F + M + F + K + F).$$

3. In a more complex type of cimaruta certain emblems hold secondary emblems. For instance, the fist (F) and the cock (C) may hold the lotus-flower (L), and the moon (M) may support the cock (C). This is represented by the formula

$$R_3[F(L) + K + M(C) + C(L) + F].$$

Similar formulæ may be of use in the representation of other objects, such as the mano pantea and the Barone lamps.

The majority of the emblems combined with the cimaruta have been associated with the cult of Diana, but others are apparently operative as averters of the evil eye by their insulting gestures; with others the attribute of watchfulness has been associated.

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9. *Records of Palæolithic Man from a New Locality in the Isle of Wight. By* Professor E. B. Poulton, *D.Sc., F.R.S.*

A series was exhibited of palæolithic implements and flakes from the north-east coast of the Isle of Wight, a locality in which palæolithic implements had not previously been found. The implements had been traced from the gravel shore, where implements were found by the reader of the paper, to the gravel escarpment itself by Miss Moseley. The series exhibited every stage, from the simple flake to the finished implement, clearly indicating that the implements had been manufactured *in situ.*

Sub-Section of Anthropography.

1. *The Persistence in the Human Brain of certain Features usually supposed to be distinctive of Apes. By* G. Elliot Smith, *M.D.*

The study of a large series of simple human brains belonging to various lowly (chiefly African) peoples has revealed the fact that the human brain may retain many features that are commonly supposed to be distinctive of apes. Although this statement can be applied to almost every part of the brain, it is especially in the occipital region of the cerebral hemisphere that the supposed distinctively simian characters are most exactly reproduced. This is due to the fact that the cortical area especially concerned with the reception of visual impulses is as well developed in the anthropoid apes as in man. The *form* of this visual area in the human brain is often greatly distorted, in an almost purely mechanical way, by the enormous increase in the size of the cortical area in front of it; but however much its shape in man may differ from that of the apes, its structure is identical.

It is a most curious and enigmatic fact that the simian resemblance is much more often retained in the left than in the right occipital region. The reason for this is that the visual centre retracts towards the mesial surface to a distinctly greater degree on the right than the left side of most human brains; it is pushed backward, as it were, by a very great and quite a symmetrical expansion of the right inferior parietal region.

This asymmetry of the brain often exercises an obvious influence on the shape of the cranium.

The study of the form of the visual centre and its sulci in series of brains affords information of great anthropological value.

Although large 'Affenspalten' may occur in people of various races, they are rarely symmetrical in the two hemispheres, except in the Negro races. In this, as well as in many other features, the Negro brain is distinctly more pithecoid than the brains of any other people known to the writer.

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2. *A Note on the Brain of a Fœtal Gorilla. By* W. L. H. Duckworth, *M.A.*

The external features of this specimen have been described by the author in the 'Journal of Anatomy and Physiology' and in the 'Archiv für Anthropologie.' Both memoirs are illustrated, and the latter contains a skiagraph of the specimen. The external features of the brain are now considered alone. When exposed, no *sulci* were observed on the lateral aspects of the *cerebrum*; shortly after the first exposure a cleft was formed in the left hemisphere, and was shown in a photograph accompanying this communication.

But the interest of the case is really concentrated in the appearances presented by the mesial aspect of the left hemisphere, a view of which was shown on the screen.

Two important *sulci* are to be seen. That which is more anterior in situation corresponds to the *Bogenfurche* of His; the second and more posterior *sulcus* seems to represent the calcarine, or possibly the paracalcarine, element. The problem is to solve the question as to the nature of these sulci, *i.e.* whether they are natural, or simply due to decomposition. In the human cerebrum, it is generally conceded that the *Bogenfurche* is an artificial product, though I believe that His did not admit this. As to the calcarine *sulcus*, the tendency is to consider it as naturally present at a very early period. In the gorilla brain shown I see no means of discriminating between the two *sulci*; but considering the occasional late appearance of the calcarine *sulcus*, as shown in one of Cunningham's figures, it seems as though both should be regarded as of artificial origin. It remains to note that Professor Retzius is of opinion that in this gorilla brain the calcarine *sulcus* is, so to speak, 'genuine.'

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3. *Some Variations in the Astragalus.* *By* R. B. Seymour Sewell, *B.A.*

The bones examined number upwards of 1,000 and are mainly of Egyptian origin.

As regards the angles which the collum makes with the corpus these specimens are intermediate between the Europeans and the anthropoid apes. The adoption of certain postures produces changes in the articular surfaces; thus in squatting we have a formation of facets on the neck, and in the sartorial position we get changes in the facies malleolaris medialis and a formation of an accessory facet, facies accessoria externa.

The process of eversion of the foot has also caused structural changes in the bone, certain specimens from Borneo being intermediate between the Egyptian and the anthropoid apes.

Occasionally we find accessory facets present. The facies accessoria inferior may be fused with either the facet in front or behind, and in rare cases with both.

We occasionally find the middle and posterior calcaneal facets fused directly; and in rare cases the anterior calcaneal facet is absent. The os trigonum is very variable both in size and shape; usually it takes no part in the formation of the sulcus musculi flexoris hallucis longi, but in very rare cases this groove may be formed either partly or entirely by this ossicle.

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4. *Some Varieties of the Os Calcis.* *By* P. C. Laidlaw.

From the collection of bones in the Cambridge University Museum I have picked out a number which present variations of an interesting nature.

The varieties I have chosen fall under six heads:—

(1) The variability of the processus trochlearis seems to show that it is not developed from a separate ossicle, as Professor Pfitzner suggested.

(2) The external plantar tubercle.

Its variations in man, its absence in the anthropoids and its probable development, the anatomy of the soft parts in man and the chimpanzee, show that it is a structure developed for the more ready maintenance of the upright position.

(3) Calcaneus secundarius of Gruber.

(4) Os sustentaculi proprium.

(5) The processus trochlearis of Kyrtl and its variation seem to show that it is not necessarily pathological.

(6) Variations in the facets met with in the bone—

Due to (*a*) ossicles.

(*b*) Other factors.

The projection of the heel is more limited in Europeans than in the ancient Egyptians owing to backward extension of the fascia articularis posterior.

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5. *Facial Expression.* *By* F. G. Parsons.

The author pointed out the unreliability of a superficial judgment of the physiognomy, and illustrated the point by reference to portraits of Judge Jeffreys and General Wolfe respectively. He then proceeded to consider the relation of the chief lines of expression to the subcutaneous muscles of expression, pointing out that expression may be determined not only by the muscle that acts, but also by the degree to which it is put in action; also that the complication induced by the concomitant action of several muscles in the production of expressions necessitates a careful analysis in each instance. With the aid of an anatomical diagram the several muscles involved were enumerated and their action described. Illustrations were drawn from a series of portraits in the National Gallery, and the author concluded by expressing his belief that, in spite of the abuse of physiognomical studies in the past, there was still hope that systematic research would be productive of sound and even brilliant results.

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6. *Anthropometric Identification: a New System of Classifying the Records.*[1] *By* J. Gray, *B.Sc.*

The weak point of the Bertillon system of anthropometric identification is the method of classifying the records. As is well known, the records are subdivided four times into three groups, each group lying between fixed limits of four different dimensions. The cards on which the records are written are stored in a cabinet containing eighty-one drawers, each one of which contains all cards between specified limits. The process of identification consists in finding the drawer between whose limits the person to be identified lies. There may be considerable difficulty in finding the required drawer if the dimensions of the person to be identified lies near the margin of limits in one or more dimensions. It will be necessary, then, to make more than one search. Dr. Garson, in working the Bertillon system at Scotland Yard, found that only 61 per cent. of the identifications were made by one search. To get over this difficulty it is proposed to abolish fixed subdivisions. If the complete dimensions of each individual were written on a single card these cards would be arranged according to the first dimension as in a card catalogue. When we wish to ascertain whether a person who has just been measured has already a record card in the register we form two limits by adding on and subtracting an amount equal to the extreme variation likely to occur in measurement. For example, in case of a head-length or breadth, add on and subtract 4 mm. Take out all the cards between the limits thus found. The required card, if present, must be in this packet of cards. Now rearrange the cards in this packet according to head-breadths. Find the limits of variation for the measured breadth in the same way as described above for the length. Take out all the cards from the packet between the limits of breadth, and so on with the other dimensions. If a sufficient number of dimensions are taken, only one card will be left after the final separation, if the record of the person to be identified is present. By this system the effects of considerable inaccuracy in measurement can be neutralised by measuring a large number of dimensions. In no case is more than one search necessary to determine whether the record of the person measured is present in the register or not. The process of searching may be very much simplified by the use of charts on which the numbers of the record cards are stamped at the points indicated by two dimension co-ordinates. This system of classification would probably remove the chief objection to the Bertillon system, which is otherwise much superior to the finger-print system, in which the uncertainty at the margins of groups is very great.

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[1] To be published in full in *Man.*

7. *Graphical Representation of the various Racial Human Types.* *By* W. L. H. Duckworth, *M.A.*

The methods of representation devised by Keane, Flinders Petrie, Thomson, and Stratz were reviewed. The author's proposal is to adopt the simile of a protoplasmic organism with processes corresponding to the several morphological types. The communication was illustrated by diagrams.

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8. *Exhibit of Amorite Crania.* *By* Professor A. Macalister, *F.R.S.*

Professor Macalister exhibited a number of skulls from the excavations made by the Palestine Exploration Fund at Gezer, representing the ethnology of the third and fourth strata, and also, for comparison, some from the tombs of the last stratum of Maccabean age. No skulls belonging to the first and second strata are represented in the series, the peoples of these strata having practised cremation.

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9. *Report on Anthropometric Investigations among the Native Troops of the Egyptian Army.*[1]—See Reports, p. 339.

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10. *The Variability of Modern and Ancient Peoples.* *By* C. S. Myers, *M.D.*

It has been generally supposed that modern peoples deviate more widely than ancient peoples from their respective means. The writer's investigations upon the Egyptian fellahin, however, lend no support to this supposition, alike in length, breadth, and horizontal circumference of head and in cephalic index. The variability of the modern population of Ḳena and the neighbouring district is not sensibly different from that of inhabitants of the same region six or seven thousand years ago, as deduced by Miss Fawcett and others from the Naḳada collection. So, too, the variability in cephalic index of ancient Bavarian skulls is found to be almost identical with that of the modern Bavarian population; and the variability of the cephalic index in modern French and English does not exceed, but is probably less than, that in ancient Gaulish and British skulls respectively.

More evidence is urgently needed, but what little we have supports the contrary hypothesis that modern and ancient populations living under like conditions of country and climate differ little in variability. Professor Karl Pearson, on the other hand, supposing that a diminishing struggle for existence encourages the persistence of individuals showing greater variability, believes that variability increases with increasing civilisation. The opposite view, however, appears tenable, that stringent selection encourages greater variability. It explains why in several features the oppressed Copts show greater variability than the Mahommedan population of Egypt, and the Whitechapel series of skulls of the sixteenth century is more variable than the general upper middle and upper class population of modern England. The more prosperous community tends to homogeneity; in other words, to regression towards its mean.

TUESDAY, AUGUST 23.

The following Papers and Report were read:—

1. *Note on Prehistoric Archæology in Greece.*[1] *By* Dr. P. Kabbadias.

The author pointed out that few traces of the Stone Age had been found in Greece, the early settlements in all probability having been reoccupied by settlers belonging to the later Mycenæan civilisation. In Thessaly neolithic settlements

[1] Published in full in *Man*, 1904, 112.

had been found, though the Acropolis, where sporadic specimens of stone implements had been found, was undoubtedly first peopled in the Bronze Age. The excavations of the Archæological Society of Athens in the Ægean and the Peloponnese had so far brought to light no traces of a civilisation prior to that of the Bronze Age. Pile dwellings were not represented in Greece, their place being taken by fortified towns built of stone. After an allusion to the progress of palæontology in Greece and the founding of an anthropological museum at Athens, the author concluded his paper with a reference to the excellent work of the British School at Athens.

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2. *Report on Archæological and Ethnographical Explorations in Crete.* *S*ee Reports, p. 321.

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3. *Preliminary Scheme for the Classification and approximate Chronology of the Periods of Minoan Culture in Crete, from the close of the Neolithic to the Early Iron Age. By* ARTHUR J. EVANS, *D.C.L., F.R.S.*

The accumulated results of recent Cretan discovery, and in a principal degree those of the Palace site at Knossos, have greatly added to the data for fixing the comparative chronology of the early Cretan civilisation. A preliminary attempt is here made to classify, and even to delimit within approximate chronological landmarks, the successive phases of culture that in Crete extend themselves between Neolithic times and the Early Iron Age. To this period as a whole it is proposed definitely to attach the name Minoan, as indicating the probable duration of successive dynasties of priest-kings, the tradition of which had taken abiding form in the name of Minos. It is proposed to divide this Minoan Era into three main periods, Early, Middle, and Late, each with a first, second, and third sub-period. The use of the word 'Mycenæan' requires radical revision, the Mycenæan culture being in its main features merely a late and subsidiary outgrowth of this great 'Minoan' style, when the fine motives of the last Palace period are already seen in a state of decadence. This decadence is already observable in the sherds found in the Palace of Tel-el-Amarna (c. 1400 B.C.), and even in somewhat earlier relics associated in Egypt, Rhodes, Mycenæ, and elsewhere, with cartouches of Amenhotep III. and his queen. The recently discovered cemetery at Knossos shows the less decadent forerunners of this style, though still later than those of the last Palace period, the end of which is thus carried back at least to the close of the sixteenth century B.C. The third Late Minoan Period may thus be roughly dated between 1500 and 1100 B.C.

The second Late Minoan Period receives its fullest illustration in the remains of the latest Palace period at Knossos. The fine 'Palace style' which had here grown up, with its strong architectonic elements, common to sculpture and wall-painting as well as to ceramic design, must itself represent a considerable period of development. Its latest stage shows a great correspondence in its artistic and other products with those associated with the Kefts and 'Peoples of the Isles of the Sea' on Egyptian monuments of the sixteenth century B.C., and the contents of the recently discovered royal tomb at Knossos include alabaster vessels belonging to the beginning of the XVIIIth Dynasty. The earlier phases of this style must go back at least a century before this. Middle Minoan II. may thus extend from about 1700 to 1500 B.C. This period corresponds with that of the shaft graves at Mycenæ, and to that period also belong the abundant Palace archives in linear script (Class B).

An earlier stage of the later Palace, marked off from the latter by an extensive catastrophe, has now been clearly made out, especially from the rich contents of the Temple repositories. It is an age of ceramic transition, and at the same time the period when naturalistic art reached its highest perfection in Minoan

Crete, as is shown by such masterpieces as the faïence relief of the Wild-goat and Young. An earlier system of linear script was now in use (Class A). The alabaster lid with the name of the Hyksos King Khyan and a monument belonging to the close of the XIIIth Dynasty must be ascribed to this historic stratum, which may be approximately placed between 1900 and 1700 B.C.

The 'Middle Minoan' Age, which lies beyond the periods enumerated, is especially characterised by the development of the polychrome style of vase painting on a dark ground. This, too, is the period of the conventionalised pictographic script which precedes the linear. During the last division of this period—Middle Minoan III.—which lies about the end of the third millennium B.C., we see a certain falling off in the polychrome style, accompanied, however, with a greater naturalism, as shown in the moulding of reliefs and in the types of gems.

The second Middle Minoan Period is that during which this polychrome, or so-called 'Kamares' style, reached its acme, and the beginning of this stage is approximately dated by the painted sherds found by Professor Petrie in the rubbish-heaps of Kahun, dating from the time of Usertesen II. of the XIIth Dynasty. Taking as a mean estimate Lepsius's calculation, this brings us to about 2300 B.C. If we accept the chronological calculations of Professor Petrie and others, the date would be nearly 2700 B.C. In any case, the Cretan evidence must be taken to exclude the extreme bringing down of the XIIth Dynasty date to the borders of the XVIIIth, which has lately found favour. Other proofs of XIIth Dynasty contact are found on the seals of this period.

The Kahun deposit includes objects of the simpler style which belongs rather to the first Middle Minoan Period, and gives us, therefore, a *terminus ad quem* for this well-marked stratum. The influence of Middle Empire designs is already well marked on the seal stones of this time, which, unlike the latter, are almost exclusively cut on soft material. The ruder class of conventionalised pictographs is seen on seal impressions from deposits of this date. Allowing some time for the gradual development of the fine Middle Minoan polychrome style, the beginning of the first period of this great age may be reasonably thrown back at least to the middle of the third millennium B.C. Adopting the more liberal chronology, it would reach back nearly to the beginning of that millennium.

Beyond this date lies another long cycle of nascent culture, included in the various phases of the Early Minoan Period. The prevailing decorative style is now geometrical, generally dark ornament on a light ground, but the dark glaze slip itself goes back to the confines of the Neolithic Period. The surface of the clay is often varied by a network of raised lines, irregular protuberances, and thorn-like projections—sometimes painted over with geometrical designs—and this raised decoration was largely combined with polychrome in the succeeding period. The vases have often a high neck, and the hand-moulding of many vessels is supplemented by paring with a knife. The old hand-polished, dark-faced ware of Neolithic times survives throughout, but is most frequent in the earlier phases of this period. We see, moreover, the taking over of incised designs of the older class in the painted decoration.

A section opened below the pavement of the West Court shows a distinct stratification of floor-levels belonging to this period. The lowest or sub-Neolithic stratum there brought out shows light-ground technique already beginning, as a consequence of the introduction of the potter's oven. The old black-faced hand-polished Neolithic class that survives beside this is also now better cooked within. The spiral now appears for the first time on steatite vessels and incised pottery, whence it is taken over in painted designs during the next period. Its introduction appears to be due to Cycladic influences otherwise traceable at this time.

This Early Minoan Period, like the succeeding, is characterised by its special class of seal stones—in this case presenting pictographic designs in their more primitive stage. Many seals show the adaptation of motives from a VIth Dynasty class of button seals. The forms of certain Minoan stone vases also take them back to the Early Dynastic Period of Egypt, and syenite and other vessels from the Palace site at Knossos are of Egyptian fabric, belonging to one or other of the first four dynasties. Whether or not black hand-painted vases found by

Professor Petrie at Abydos with Ist Dynasty remains were actually imported from Crete, their surface and texture so closely resemble those of the earliest Minoan or sub-Neolithic Period that we are justified in inferring a certain contemporaneity. These Egyptian connections show that it would not be safe to bring down the beginnings of the Early Minoan culture later than the middle of the fourth millennium before our era.

The section in the West Court of the Palace shows the earliest Minoan floor-level at a depth of 5·32 metres below the surface. Below this again are at this point 6·43 metres of Neolithic strata. Assuming that the average rate of deposit was fairly continuous, this gives an antiquity of about 12,000 years for the earliest Neolithic settlement at Knossos.

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4. *Painted Vases of the Bronze Age from Palaikastro.* *By* R. M. Dawkins, *B.A.*

The resemblance of the series of styles found at Palaikastro with those found elsewhere in Crete makes it possible to use the terms used at Knossos, 'Minoan,' &c., in describing the successive styles of Bronze Age vases. A series of slides was shown giving first geometrically painted vases of the Early Minoan period, then polychrome vases of the Middle Minoan period, and lastly examples of the three phases of the Late Minoan period. This series of slides showed the development of the styles of design, from their geometrical beginning with patterns imitated from the earlier incised ware, through the freer style of the Middle Minoan to the naturalistic style of Late Minoan I., and then exhibited the process of formalisation, which ends with the rigid formal style of decoration that characterises vases of the Late Minoan III. time. At the same time it showed the growth of the light-on-dark polychrome style of the Middle Minoan, and its gradual change through the abandonment of subsidiary colours to the monochrome dark-on-light style of the later parts of the Late Minoan period. Throughout, attention was called to the painted patterns rather than to the shapes of the vases.

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5. *Excavations at Heleia (Palaikastro) and Praisos in Eastern Crete.* *By* R. C. Bosanquet, *M.A.*, *F.S.A.*

The British school again excavated at Palaikastro, the Minoan town which has yielded important results in two previous seasons, from March 25 to June 17 with the help of grants from the Cretan Exploration Fund (including a gift of 100*l.* from Mr. George Macmillan), Emmanuel College, and the Fitzwilliam Museum. The expedition consisted of Mr. R. McG. Dawkins, Fellow of Emmanuel College, Cambridge; Mr. Heaton Comyn, architect; Mr. C. T. Currelly, of the Egypt Exploration Fund; Mr. J. L. Stokes, Scholar of Pembroke College, Cambridge; and the Director.

1. *Late Palace.*—The further excavation of Block Delta, the largest and best built of the *insulæ* opened up last year, showed that this was the palace or Government House of the latest Mycenæan period. It has an imposing façade of huge ashlar blocks, and the general plan of the ground floor, broken up by light wells and other paved areas, can be recovered; but it has been much plundered, and many walls of this exceptionally fine masonry have been destroyed in recent years. Some well-preserved magazines yielded an important series of painted vases, and some terra-cotta figures of a goddess, in one case grasping a snake. Careful dissection of the lower strata, when they were not obliterated by the massive substructures of the palace, revealed remains of three earlier periods. The sequence of some early varieties of pottery was determined by Mr. Dawkins, and plans illustrating the stratification prepared by Mr. Comyn. Fragments of an ostrich-egg, found at a very low level, point to early intercourse with Africa.

2. *Other Work in the Town.*—The main street was followed in both directions, and two low hills to the west and south-west of it were excavated. On one of

them four blocks of somewhat poor houses were opened up, and yielded some very valuable finds, notably two delicately carved ivory statuettes, a large bronze ewer, and a richly painted bath. The ivories may be importations from Egypt; while an ivory plate, carved with conventional crocodiles, betrays indirect Egyptian influence. The other hill was covered with houses of a better type divided by what may prove to be a continuation of the main street.

3. *Cemeteries.*—The curious ossuaries of the middle Minoan period were further excavated. Among the objects found were seals of ivory and steatite, a miniature gold bird, and small models of a dagger and of sickles. A very early burial-place, discovered by Mr. Dawkins near the headland of Kastri, contained beaked jugs of an exaggerated pattern and a remarkable clay model of a boat. A later cemetery, containing *larnax* burials, yielded bronze implements, beads, and vases like those in the palace magazines. In searching for tombs south of the town Mr. Currelly discovered a steatite libation-table on which are engraved seventeen characters of the Minoan linear script.

4. *Temple.*—In trenching the area within the Minoan town, where scattered remains of a Hellenic sanctuary have long been known to exist, Mr. Bosanquet found a broken slab of grey marble inscribed with a Doric hymn in honour of the youthful Zeus. The lettering is of the Roman age, the composition genuinely archaic. It refers to his nativity in the Dictæan cave, and leaves no doubt that we have here the temple of Zeus Diktaios, the territory of which was a subject of dispute between Hierapytna and Itanos until the matter was settled by arbitration in the second century B.C. It can hardly, however, be the temple mentioned by Strabo as having existed at or near Praisos before the destruction of that city, for Praisos is five hours' ride from Palaikastro.

We may now restore to the plain of Palaikastro its classical name of Heleia mentioned in the arbitration award.

5. *Researches at Praisos.*—The steep west face of the Altar Hill (the top of which was cleared in 1901) had never been examined. Numerous architectural members and fragments of inscriptions have now been found here by Mr. Bosanquet, built into dykes or buried under fallen masses of rock. A temple on the summit seems to have been demolished and its materials thrown over the cliff, presumably when the Hierapytnians destroyed the town. In view of the public character of some of the inscriptions it is probable that this was the chief sanctuary of Praisos, possibly the temple of Dictæan Zeus mentioned by Strabo. The most important inscription is one in the ancient Eteocretan language, which was hitherto known only from two inscriptions, both found on this hill. The newly discovered document is in Greek characters of the third or fourth century before our era.

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6. *The Linguistic Character of the Eteocretan Language.* *By* Professor R. S. Conway, *Litt.D.*

The author illustrated his subject by an inscription discovered by Mr. Bosanquet at Praisos in June 1904. The text is too fragmentary to admit of even conjectural interpretation, but presents several new features of interest in phonology and morphology not inconsistent, in the author's judgment, with the conclusions as to the Indo-European nature of the language which he has drawn from the two inscriptions previously known.

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7. *A Find of Copper Ingots at Chalcis.* *By* R. C. Bosanquet, *M.A.*

The author described a find of copper ingots at Chalcis, in Eubœa. This was a shipwrecked cargo of nineteen ingots, weighing from 25 to 40 lb., and perhaps dating from the Bronze Age. Similar ingots or talents of copper had been found at Mycenæ, at Phæstus in Crete, and in Cyprus and Sardinia. A recent discovery of bronze axes in an ancient copper working on Mount Othrys might be taken as evidence that the copper ores of Othrys were known in Mycenæan times. Chalcis may have been so called as being the chief emporium, though not the real source,

of this copper. The relative abundance of such hoards of bronze axes suggests that they were used as a means of exchange, especially in Crete, where many axes have been found which have a haft-hole too small to admit a serviceable handle. It is remarkable that in historic times in Crete the word πέλεκυς (axe) is said to have denoted a fraction of the talent.

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8. *The Geometric Period in Greece. By* Professor OSCAR MONTELIUS.

The Geometric period succeeds the Mycenæan period in Greece and in the isles of the Ægæan Sea. In the western part of Asia Minor, where the author thinks that the Mycenæan culture continues long after its disappearance in Greece, the Greek Geometric style is not represented.

The Mycenæan period is a part of the Bronze Age; iron began to be used only just at the end of the period. All the Geometric period belongs to the Iron Age. Consequently, in the Mycenæan period, swords and other weapons were of bronze; in the Geometric period, swords and many other weapons were of iron.

At the end of the Mycenæan period the fibula (safety-pin) became known in Greece. It is most interesting to follow the evolution of the fibula through the Geometric period.

Most of the remains from this period are ceramic. The technique is about the same as in the Mycenæan time; the vases are made of very pure clay, and wheel-made; the ornaments are painted with glaze colours. Some of the forms are also derived from those of the preceding period. But the predominant ornaments are different. The Mycenæan flowers as well as the sea-animals have disappeared, and the animals of the Geometric period—generally horses and birds—are not so well drawn as in the preceding time. Most of the ornaments are geometric, some are rectilinear (mæander, zigzag, &c.,): the *swastika,* extremely rare in the Mycenæan period, is very common. Others are curvilinear: spirals, concentric rings joined by tangents ('false spirals'), concentric circles without such tangents, &c. In Attica, men, women, horses, chariots—forming scenes of funeral solemnities and races—are sometimes painted on the vases, but the figures are drawn in a most infantile way.

The Geometric style is not derived from the countries to the north of Greece. All the ornaments characteristic of this style are earlier in Greece than in other parts of Europe.

The Geometric style is a continuation of the Mycenæan one, but it is much inferior to this, which cannot be accounted for only through the migrations of the Dorians, because the difference between the Geometric and the Mycenæan style is as great in Attica—where the Dorian invaders did not come—as in other parts of Greece. The explanation may be that the foreigners (Tyrrhenians or Pelasgians), to whom, in the author's opinion, the Mycenæan culture was due, had been expelled, and the Hellenic people had not yet reached the same high degree of civilisation as these foreigners.

The Geometric period began in the twelfth century B.C., and lasted a very long time. It can be divided into the following parts:—The first Geometric period (in Attica, the older 'Dipylon vases'); the second Geometric period ('Phaleron vases' and skyphoi); the third Geometric period ('pre-Corinthian' vases). This last period ends about 700 B.C.

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9. *The Latest Discoveries in Prehistoric Science in Denmark. By* Professor VALDEMAR SCHMIDT.

(1) Investigations have been made in recent years in the National Museum of Copenhagen on the musical properties of the famous trumpets of the Bronze Age, called in Danish generally *Lur.* These instruments are so well preserved that they are now played annually in public on St. John's Day.

(2) The oldest period of the Danish Stone Age, only recently discovered, is earlier in time than the 'kitchen-middens' and much anterior to the dolmens,

from which the bulk of the well-known Danish flint implements have been derived. In a peat-bog in Western Zeeland, near a small harbour called Mullerey, not far from the Great Belt, were found many objects of stone and wood of a primitive order, evidently from an early part of the Stone Age. A careful study of these objects and of their position in the bog proved that the prehistoric inhabitants who left or dropped those implements must have been dwelling on rafts in the middle of a lake. It was indeed a 'lake dwelling,' but not on piles like the lake dwellings of Switzerland and Northern Italy, for in this case the dwelling of the early inhabitants was floating on the surface of the water.

(3) It has been discovered during the last few years what kinds of grains of corn, wheat, and barley were in common use in the different prehistoric periods of Denmark. As in many other countries, a large quantity of earthen vessels or bits of broken pottery have been found in the prehistoric tombs, and on the site of old dwellings. In examining these objects one finds sometimes in the pottery (but not very frequently) impressions of grains of corn, which give exactly the shape of the grain. Thus we are able, by comparison, to determine the variety of grain used in those prehistoric times. It is to be supposed that the places where the pottery was made in prehistoric times had sometimes served, a little before, as a threshing-floor. The Museum in Copenhagen has gradually been acquiring the most important pieces of this kind found in Denmark, and preserved formerly in private collections.

(4) Special study has been devoted lately to the distribution of tumuli in different parts of Denmark. Archæological maps have been made in the last few years of a great part of the country; and all tumuli, all burial and dwelling places, and all localities in which prehistoric implements have been found, are marked on these maps. The Director of the Prehistoric Museum of Copenhagen, Dr. Sophus Müller, who has been the leader in this cartography, has recently stated that the tumuli always follow ancient roads through the country, and that lines of tumuli always lead towards the fords of the larger rivers, and avoid the swampy ground. It is to be supposed that the people who were buried in the tumuli had dwelt near their graves, and traces of such dwelling-places have been found at some few places.

WEDNESDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *Classification Sociale.*[1] *Par* EDMOND DEMOLINS.

Ceci est un essai pour substituer à la classification élémentaire et artificielle de Le Play, qui est aujourd'hui insuffisante, une classification naturelle des Sociétés humaines. Au lieu de classer les types sociaux d'après un seul caractère, ce qui est artificiel, j'entreprends de faire le classement d'après l'ensemble des caractères, actuellement mieux connu, grâce aux progrès de la science.

Ce travail est le résultat de vingt-cinq années d'études, poursuivies sans interruption depuis la mort de mon maître Frédéric Le Play.

Les deux Formations sociales.—Toutes les Sociétés qui existent à la surface du globe peuvent se ramener à deux grandes divisions:

1° La *Formation communautaire,* dans laquelle on cherche à résoudre le problème social, en s'appuyant sur la communauté plus que sur soi-même.

2° La *Formation particulariste,* dans laquelle on cherche à résoudre le problème social, en s'appuyant sur soi-même plus que sur la communauté.

La première de ces deux Formations domine dans l'Orient et explique son immobilité; la seconde domine dans l'Occident et explique son mouvement progressif.

Les six Genres.—Ainsi que l'indique le tableau ci-après, chaque Formation

[1] To be published in full (in English) in *Man*, 1905.

sociale se divise en trois *genres: stable, instable, ébranlé,* pour la Formation communautaire; *ébauché, ébranlé, développé,* pour la Formation particulariste.

Les Groupes et les Régions.—Chacune de ces deux subdivisions du genre est formée de circonscriptions géographiques qui présentent des caractères sociaux communs. Le nombre des Groupes et des Régions est indéfini et ira toujours en augmentant, à mesure que la science aura découvert des phénomènes nouveaux, ou qu'elle aura mieux analysé les phénomènes déjà observés.

Dans chaque Groupe et dans chaque Région les types sont classés dans l'ordre de la *complication sociale croissante.* La complication résulte, le plus ordinairement, de la nature et du développement du travail dominant, suivant cet ordre, révélé par un demi-siècle d'observations méthodiques: Art pastoral, Pêche, Chasse, Cueillette, Culture, Exploitation minière, Fabrication, Transports et Commerce.

La Science sociale a déjà à sa disposition un *instrument d'analyse,* la *Nomenclature* établie par Henri de Tourville. J'ai l'espoir qu'elle va posséder maintenant un cadre rigoureux, pour enregistrer et classer méthodiquement les résultats acquis par l'analyse.

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2. *Further Excavations on a Palæolithic Site in Ipswich.*[1] *By* NINA FRANCES LAYARD.

At the meeting of the British Association held in Belfast in September 1902 palæolithic implements from the brick earth of Ipswich were shown. As the pit from which they were taken was being worked for clay, and a large number of men were employed, it was impossible to make accurate observations either with regard to geological conditions or the precise position in which the flints were found.

With a view to a more thorough examination of the site a committee was appointed in October last to arrange special excavations for this purpose.

The pit is situated on a plateau above the town of Ipswich. A slight depression appears to indicate the position of a former valley cut through boulder clay and now silted up, or a small lake formed on the uneven surface of the land.

An area measuring ten yards by six was marked out and worked from the surface down to the implement-bearing bed.

Two workmen only were employed, and their work was daily superintended by the writer, who took measurements of the depth at which every flint was found.

It had already been noticed that implements occurred at depths varying from 8 to 12½ feet in other parts of the clay pit, but it was proved by working regularly from west to east of the pit that they were all in reality on one floor, which gradually rose several feet from what appeared to be the margin of a former lake. Only in one instance out of forty was a tool found lying directly above another.

A red gravel-stain in the clay marked out the position of the palæolithic bed, and immediately below this the flints were always found. Guided by this ferruginous stain the bed could be traced with tolerable precision.

Besides forty implements a number of flints showing human work were discovered.

The tools were of considerable diversity of form, and it was noticed that all the oval and ovate sharp-rimmed implements, of which there were fifteen examples, were in and under compact clay, while the gravels, which sloped down to the clay, contained a large number of rougher tools of other shapes.

The position of the oval implements possibly points to their particular use, for if, as Sir John Evans has suggested, they may have been missiles for hurling at water-fowl, the discovery of them in the shallows of what was formerly a lake bottom tends to confirm this view. It was also significant that the only flints discovered in the clay were implements, no natural pebbles being found with them. This could not have been the case if they had been washed down from the adjoining gravels. Three fine specimens, which were lying close together, are

[1] To be published in full in *Journ. Anthr. Inst.*, xxxiv.

almost exactly similar, and must have been the work of the same hand. The ogival curve is very pronounced in them. The tools found in the clay are almost entirely devoid of patination, the edges being as sharp as when newly fashioned.

Among those from the gravel was a minute, delicately worked implement, which appeared to have been made in imitation of a larger pointed weapon. This is believed to be a toy-tool made for a palæolithic child. Such tools are rarely found in England, but have been recognised on the Continent. It may, however, be a forerunner of the neolithic arrowhead, though the finding of an equally minute ovate implement, for which it is difficult to imagine a use, is against this explanation.

An implement of quite unique pattern—also found in the gravel—may be described as a cutting tool with a concave edge.

Side by side with implements of the roughest possible work were some carefully wrought specimens.

On the chalky crust of a few flints either tool-marks or glacial scratchings are very distinct.

A boring made from the greatest depth at which tools were found, namely, 12½ feet, showed that the boulder clay was 15 feet below the implements. This demonstrated that the depression had been partially silted up before man's appearance, and that the silting continued later, burying the remains and filling up the valley.

The only remains found were fragments of the teeth and tusks of elephas sp., rhinoceros, ox, and deer; but these were 2½ feet below the implements in coarse gravel.

Below this, again, in the underlying clay, were blackened thread-like fibres, probably the rootlets of water plants.

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3. *Report on the Lake Village at Glastonbury.*—See Reports, p. 324.

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4. *Reports on Excavations on Roman Sites in Britain.*—See Reports, p. 337.

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5. *Some Funeral Customs of the Todas.* *By* Dr. W. H. R. Rivers.

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6. *On a Votive Offering from Korea.* *By* E. Sidney Hartland.

The author exhibited a votive offering from a shrine on the top of the Charyong Pass, in Korea, about 61 *li* south of Gensan. It is a rough iron casting, 6 inches long, nearly 2 inches high, and weighing about 1¼ lb., of an animal, said to be a tiger. A shrine of some kind is found at the top of every pass in the south and south-east of Asia. Usually it is a mere heap of stones, or of sticks, or leaves, to which the passing traveller is expected to add his contribution. Sometimes, however, it is more pretentious, and attracts more shapely and even valuable offerings. It is, as a rule, dedicated to the local genius or divinity. The Korean mountains are infested with tigers, which are greatly feared by the natives, and to which supernatural powers are attributed. They were formerly worshipped, and it is probable that the cult still exists. If so, the shrine from which this offering was taken may be dedicated either to the tiger itself or to the mountain-god under that form.

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7. *Notes on the Fulahs of Nigeria.* *By* E. F. Martin.

Nigeria is peopled by many and varied races, the seaboard being exclusively inhabited by Negro tribes, the Hinterland by Fulahs, Hausas, Nupés, &c. The three latter are mostly Mahommedans, the other tribes pagans. The land is fertile,

yielding cereals and cotton, for which there would appear to be a great future. Transport is conducted by means of carriers and pack animals. Slave raiding, for which the country was once famous, has now quite died out.

The Fulahs are the most important of the races of Nigeria. They are apparently of Eastern origin, and are similar in appearance to the Egyptian; but their own tradition makes them to have sprung from a savage aboriginal light-skinned race dwelling in the highlands between Benué and Lake Tchad. According to the Fulahs, this race is still dwelling in the interior, and the tradition is supported from independent sources.

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8. *The Bee Cult in British Folklore.* *By* G. L. Gomme, *F.S.A.*

Section I.—PHYSIOLOGY.

President of the Section—Professor C. S. Sherrington, Sc.D., M.D., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

Correlation of Reflexes and the Principle of the Common Path.

It has been lightly said that this Association meets to cultivate less muses than amusements. The two are not incompatible, and here happily the muses number not merely nine, but ten; for we surely include among the muses 'Physiologia.' Here in Cambridge our muse admits frankly that a mistake has been made about Parnassus—it is not a mountain but a flat place, almost fenny, once worried by mosquitoes, and now immune from all worries.

Perhaps the confusion between Parnassus and a mountain was due to the Gog-Magog hills. Those hills our muse has haunted and still haunts. She has votaries there; among them one who instituted her worship in this place, a teacher whose powerful appeal attracted disciples from all sides, one whose enthusiasm was, moreover, never narrowed to a single science alone, but floods all biology. With Cambridge and Physiology the name of Sir Michael Foster rises to the lips as an indissoluble sequence. So it will ever be; and it must give him pleasure, as it gives us, to have for his successor here one of his first pupils, one associated far and wide with that which Physiology treasures as always golden, the discovery of imperishable facts.

When this Section last met, two years ago, its President, Professor Halliburton, reviewed for us the existing position of chemical physiology. We cannot from the nervous system draw themes of such general attractiveness as the new biochemistry, with its startling reactions, its varied hypotheses, its *toxophores, haptophores, amboceptors,* and other fairylike agents.

Physiology studies the nervous system from three main points of view. One of these regards its processes of nutrition. Nerve-cells, as all cells, lead individual lives, breathe, dispense their own stores of energy, repair their own substantial waste, are, in short, living units, each with a nutrition more or less centred in itself. The problems of nutrition of the nerve-cell and of the nervous system, though partly special to this specially differentiated form of cell life, are, on the whole, accessible to the same methods as is nutrition in other cells and in the body as a whole.

But beside the essential functions common to all living cells, the cells of the nervous system present certain which are specialised. Among properties of living matter, one by its high development in the nerve-cell may be said to characterise it. I mean the cell's transmission of excitement spatially along itself and thence to other cells. This 'conductivity' is the specific physiological property of nerve-cells wherever they exist. Its intimate nature is, therefore, a problem coextensive with the existence of nerve-cells, and enters as a factor into every question concerning the specific reactions of the nervous system.

Thirdly, physiology seeks in the nervous system how by its 'conductivity' the separate units of an animal body are welded into a single whole, and from a mere collection of organs there is constructed an individual animal.

This third line of inquiry, though greatly needing more data from the second and the first, must in the meantime go forward of itself. It is at present busied with many questions that seem special—hence its work is generally catalogued as Special Physiology. But it includes general problems. In the time before us I would venture to put before you one of these.

When we regard the nervous system as to this, which I would term its *integrative* function, we can distinguish two main types of system according to the mode of union of the conductors—(i.) the *nerve-net* system, such as met in Medusa and in the walls of viscera, and (ii.) the *synaptic* system, such as the cerebro-spinal system of Arthropods and Vertebrates. In the integrative function of the nervous system the unit mechanism is the *reflex*. The chain of conduction in the reflex is a nervous arc, running from a receptor organ to an effector organ, *e.g.* from a sense-organ to a limb-muscle. We may still, I think, conveniently accept the morphological units termed neurones as units of construction of the reflex arc. It may be that these neurones are in some cases not unicellular but pluricellular. That question need not detain us now. Accepting the neurone as the unit of structure of the reflex chain, the characteristic of the synaptic system is that the chain consists of neurones jointed together in such a way that conduction along the chain seems possible in one direction only. These junctions of the neurones are conveniently termed synapses. The irreversible direction of the conductivity along the neurone chain is probably referable to its synapses. This irreciprocity of conduction especially distinguishes the synaptic nervous system from the nerve-net system.

The first link of each reflex chain is a neurone which starts in a receptor organ, *e.g.* a sense-organ. A receptive field, *e.g.* an area of skin, is always analysable into receptive points, and the initial nerve-path in every reflex arc starts from a receptive point or points. A single receptive point may play reflexly upon quite a number of different effector organs. It may be connected through its reflex path with many muscles and glands in various parts. Yet all its reflex arcs spring from the one single shank, so to say; that is, from the one afferent neurone that conducts from the receptive point at the periphery into the central nervous organ. This neurone dips at its deep end into the great central nervous organ, the cord or brain. There it enters a vast network of conductive paths. In this network it forms manifold connections. So numerous are its potential connections there, that, as shown by the general convulsions induced under strychnia-poisoning, its impulses can discharge practically every muscle and effector organ in the body. Yet under normal circumstances the impulses conducted by it to this central network do not irradiate there in all directions. Though their spread over the conducting network does, as judged by the effects, increase with increase of stimulation of the entrant path, the irradiation remains limited to certain lines. Under weak stimulation of the entrant path these lines are sparse. The conductive network affords, therefore, to any given path entering it some communications that are easier than others. This canalisation of the network in certain directions from each entrant point is sometimes expressed, borrowing electrical terminology, by saying that the conductive network from any given point offers less resistance along certain circuits than along others. This recognises the fact that the conducting paths in the great central organ are arranged in a particular pattern. The pattern of arrangement of the conductive network of the central organ reveals somewhat of the integrative function of the nervous system. It tells us what organs work together in time. The impulses are led to this and that effector organ, gland or muscle, in accordance with the pattern. The success achieved in the unravelling of the conductive patterns of the brain and cord is shown by the diagrams furnished by the works of such investigators as Edinger, Exner, Flechsig, van Gehuchten, v. Lenhossek, v. Monakow, Ramon, and Schäfer. Knowledge of this kind stands high among the neurological advances of our time.

But we must not be blind to its limitations. The achievement may, though more difficult, be likened to tracing the distribution of blood-vessels after Harvey's

discovery gave them meaning, but before the vasomotor mechanism was discovered. The blood-vessels of an organ may be turgid at one time, constricted almost to obliteration at another. With the conductive network of the nervous system the temporal changes are even greater, for they extend to absolute withdrawal of nervous influence. Our schemata of the pattern of the great central organ take no account of temporal data. But the pattern of the web of conductors is not really immutable. Functionally its details change from moment to moment. In any active part it is a web that shifts from one pattern to another, from a first to a second, from a second to a third, then back perhaps to the first, and then to a fourth, and so on backwards and forwards. As a tap to a kaleidoscope, so a new stimulus that strikes the central organ causes it to assume a partially new pattern. The pattern in general remains, but locally the patterns are in constant flux of back and forward change. These time-changes offer, I venture to think, a study important for understanding the integrative function of the nervous system.

If we regard the nervous system of any higher organism from the broad point of view, a salient feature in its architecture is the following. At the commencement of every reflex arc is a receptive neurone, extending from the receptive surface to the central nervous organ. That neurone forms the sole avenue which impulses generated at its receptive point can use whithersoever may be their distant destination. That neurone is therefore a path exclusive to the impulses generated at its own receptive points, and other receptive points than its own cannot employ it.

But at the termination of every reflex arc we find a final neurone, the ultimate conductive link to an effector organ, gland or muscle. This last link in the chain, *e.g.*, the motor neurone, differs obviously in one important respect from the first link of the chain. It does not subserve exclusively impulses generated at one single receptive source alone, but receives impulses from many receptive sources situate in many and various regions of the body. It is the sole path which all impulses, no matter whence they come, must travel if they would reach the muscle-fibres which it joins. Therefore, while the receptive neurone forms a private path exclusive for impulses of one source only, the final or efferent neurone is, so to say, a public path, *common* to impulses arising at any of many sources in a variety of receptive regions of the body. The same effector organ stands in reflex connection not only with many individual receptive points, but even with many various receptive *fields*. Reflex arcs arising in manifold sense-organs can pour their influence into one and the same muscle. A limb-muscle is the *terminus ad quem* of nervous arcs arising not only in the right eye but in the left, not only in the eyes but in the organs of smell and hearing; not only in these, but in the geotropic labyrinth, in the skin, and in the muscles and joints of the limb itself and of the other limbs as well. Its motor nerve is a path common to all these.

Reflex arcs show therefore the general feature that the initial neurone is a private path exclusive for a single receptive point; and that finally the arcs embouch into a path leading to an effector organ, and that this final path is common to all receptive points wheresoever they may lie in the body, so long as they have any connection at all with the effector organ in question. Before finally converging upon the motor neurone arcs usually converge to some degree by their private paths embouching upon internuncial paths common in various degree to groups of private paths. The terminal path may, to distinguish it from internuncial common paths, be called *the final common path*. The motor nerve to a muscle is a collection of such final common paths.

Certain results flow from this arrangement. One seems the preclusion of qualitative differences between nerve-impulses arising in different afferent nerves. If two conductors have a tract in common, there can hardly be qualitative difference between their modes of conduction.

A second result is that each receptor being dependent for communication with its effector organ upon a path not exclusively its own but common to it with certain other receptors, that nexus necessitates successive and not simultaneous use of the common path by various receptors using it to different effect.

Let us consider this for a moment. Take the primary retinal reflex, which moves the eye so as to bring the fovea to the situation of the stimulating image. From all the receptors in each lateral retinal half rise reflex arcs with a final common path in the nerve of the opposite *rectus lateralis*. Suppose simultaneous stimulation of two of these retinal points, one nearer to, one farther from, the fovea. If the arcs of both points pour their impulses into the final common path together, the effect must be a resultant of the two discharges. If these sum, the shortening of the muscle will be too great and the fovea swing too far for either point. If the resultant be a compromise between the two individual effects, the fovea will come to lie between the two points of stimulation. In both cases the result obtained would be useless for the purposes of either. Were there to occur at the final common path summation of the impulses received from two unlike receptors, there would result in the effector organ an action useless for the purposes of either.

When two stimuli are applied simultaneously which would evoke reflex actions that employ the same final common path in different ways, in my experience one reflex appears without the other. The result is this reflex or that reflex, but not the two together. Excitation of the afferent root of the eighth or seventh cervical nerve of the monkey evokes reflexly in the same individual animal, sometimes flexion at elbow, sometimes extension. If the excitation be preceded by excitation of the first thoracic root, the result is almost always extension; if preceded by excitation of the sixth cervical root, it is almost always flexion. Yet although the same root may thus be made to evoke reflex action of the flexors or of the extensors, I have never seen it evoke contraction in both flexors and extensors in the same reflex response. Of the two reflexes on extensors and flexors respectively, either the one or the other results, but not the two together.

Good opportunity for study of this correlation between reflexes is given in the 'scratch reflex.' When the spinal cord has been transected in the neck, this reflex in a few months becomes prominent. Stimuli applied within a large saddle-shaped field of skin (fig. 1 A) excite a scratching movement of the leg. The movement is rhythmic flexion at hip, knee, and ankle. It has a frequency of about four per second. The stimuli provocative of it are mechanical, such as rubbing the skin, or pulling lightly on a hair. The nerve-endings which generate the reflex lie in the surface layer of the skin, about the roots of the hairs. A convenient way of exciting these is by feeble faradisation. A broad diffuse electrode is applied to some indifferent part of the surface elsewhere, and a stigmatic pole is brought to some point in the saddle-shaped area of dorsal skin. This pole is formed by a minute needle with fine wire attached; it is set lightly, so that its point just lies among the hair-bulbs.

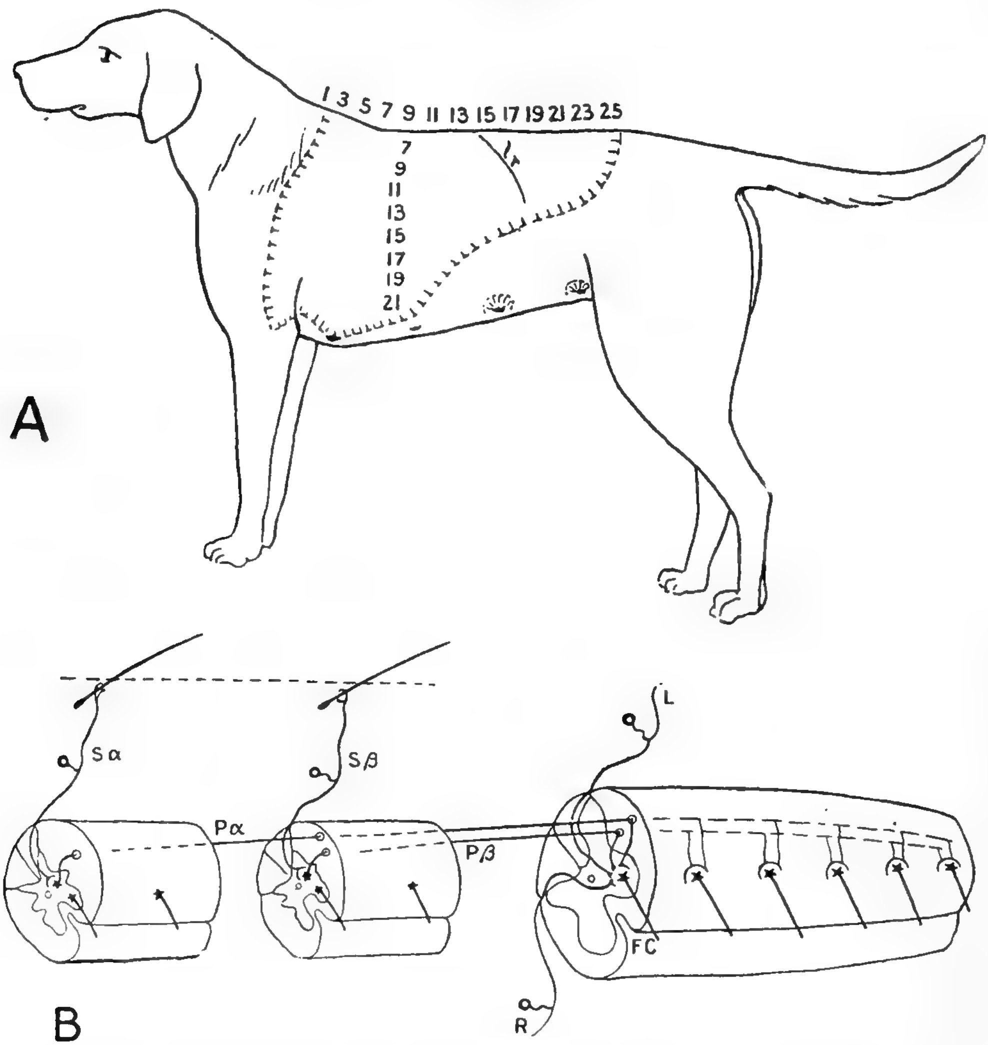
Prominent among the muscles active in this reflex are the flexors of the hip. If we record their rhythmic contraction we obtain tracings as in figs. 2, 3, 4. A series of brief contractions succeed one another at a certain rate, whose frequency is independent of that of the stimulation. The contractions are presumably brief tetani. The stimulus to the hair-bulbs of the shoulder throws into action a lumbar spinal centre, innervating the hip-flexor much as the bulbar respiratory centre drives the spinal *phrenicus* centre. In the case of the respiratory muscle the frequency of the rhythm is, however, much less.

This reflex is unilateral: stimulation of the left shoulder evokes scratching by the left leg, not by the right. Search in the spinal cord for the path of the reflex demonstrates that a lesion breaking through one lateral half of the cord anywhere between shoulder and leg abolishes the ability of the skin of that shoulder to excite the scratch reflex, but leaves intact the reflex of the opposite shoulder.

In the lateral half of the spinal cord which the reflex path descends, severance of the dorsal column does not interfere with the reflex; nor does severance of the ventral and the dorsal columns together of that side; no more does severance of the grey matter in addition. But severance of the lateral part of the lateral column itself permanently abolishes the conduction of the reflex; and it does so even if all the other parts of the cord remain intact. The path of the reflex therefore descends the lateral part of the lateral column. I enter into these details because they help toward the construction of the reflex

arc involved. For in the lateral part of the lateral column one has proved by '*successive degeneration*' that *long* fibres exist directly connecting the spinal segments of the shoulder with the spinal segments containing the motor neurones for the flexor muscles of the hip, and knee, and ankle. The course of these long fibres can be traced and their number counted. We thus

FIG. 1. The Scratch Reflex.



—The 'receptive field,' as revealed after low cervical transection, a saddle-shaped area of dorsal skin, whence the scratch reflex of the left hind limb can be evoked. *lr* marks the position of the last rib.

B.—Diagram of the spinal arcs involved. L, receptive or afferent nerve-path from the left foot; R, receptive nerve-path from the opposite foot; Sα, Sβ, receptive nerve-paths from hairs in the dorsal skin of the left side; FC, the final common path, in this case the motor neurone to a flexor muscle of the hip; Pα, Pβ, proprio-spinal neurones.

arrive at the following reflex chain for the scratch reflex: (i) The receptive neurone (fig. 1 B, Sα), from the skin to the spinal grey matter of the corresponding spinal segment in the shoulder. This is the exclusive or private path of the arc. (ii) The long descending proprio-spinal neurone (fig. 1 B, Pα), from the shoulder segment to the grey matter of leg segments. (iii) The motor neurone (fig. 1 B, FC), from the spinal segment of the leg to the flexor muscles. This last is the *final*

common path. The chain thus consists of three neurones. It enters the grey matter twice, that is, it has two neuronic junctions, two synapses. It is a *disynaptic* arc.

Now if, while stimulation of the skin of the shoulder is evoking the scratch reflex, the skin of the hind foot is stimulated (fig. 2), the scratching is arrested. Stimulation of the skin of the hind foot by any of various stimuli that have the character of threatening the part with damage causes the leg to be flexed, drawing the foot up. This reflex response to noxious stimuli of the foot is one of great potency. The drawing up of the foot is effected by strong tonic contraction of the flexors of ankle, knee, and hip. In this reaction the reflex arc is (i) the receptive neurone (fig. 1 B, L) (nociceptive) from the foot to the spinal segment, (ii) perhaps a short intraspinal neurone, and (iii) the motor neurone (fig. 1 B, FC) to the flexor muscle, *e.g.*, of hip. Here, therefore, we have an arc which embouches into the same *final common path* as *sa*. The motor neurone FC is a path common to it and to the scratch reflex arcs; both arcs employ the same effector organ, a hip flexor. And, as you see, a condition for one reflex is the absence of the other.

The channels for both reflexes finally embouch upon the same common path. The flexor effect specific to each differs strikingly in the two cases. In the scratch reflex the flexor effect is an intermittent contraction of the muscle, in the nociceptive reflex it is steady and maintained. The accompanying tracing (fig. 2) shows the result of conflict between the two reflexes. The one reflex displaces the other from the common path. There is no compromise. The scratch reflex is set aside by that of the nociceptive arc from the foot. The stimulation which previously sufficed to evoke the scratch reflex is no longer effective, though it is continued all the time. But when the stimulation of the foot is discontinued the scratch reflex returns. In that respect, although there is no enforced inactivity, there is inhibition. There is interference between the two reflexes, and the one is inhibited by the other. Though there is no cessation of activity in the motor neurone, one form of activity that was being impressed upon it is cut out and another takes its place. A stimulation of the foot too weak to cause more than a minimal reflex movement will often suffice to completely interrupt or cut short, or prevent onset of, the scratch reflex.

Suppose, again, during the scratch reflex, stimuli applied to the foot, not of the scratching but of the opposite side (fig. 1 B, R). Stimulation (nociceptive) of the foot causes flexion of its own leg and extension of the opposite. In numerous instances reflex contraction of one set of muscles is accompanied by reflex relaxation of their antagonists. The antagonistic muscle is thrown out of action. If, when the left leg is executing the scratch reflex, the right foot is stimulated, the scratching, involving as it does the left leg's flexors, is cut short concomitantly with or preparatory to the entrance into contraction of their antagonists, the left extensors. Fig. 3 shows a record of this. This inhibition of the flexor scratching movement occurs sometimes when the contraction of the extensors is minimal or hardly perceptible (fig. 3). As before, the inhibition may temporarily interrupt a reflex or may delay its onset, or simply cut it short, the result depending on the time relations of the applications of the stimuli to the conflicting arcs.

It is obvious from this that the final common path, FC, to the flexor muscle can be controlled by, in addition to the before-mentioned arcs, others that actuate the extensor muscles, for it can be thrown out of action by them. The final path, FC, is therefore common to the reflex arcs, not only from the same-side foot (fig. 1 B, L) and shoulder skin (fig. 1 B, *sa*, *sβ*), but also to arcs from the opposite foot (fig. 1 B, R), in the sense that it is in the grasp of all of them. In this last case we have a conflict for the mastery of a common path, not, as in the previous instance, between two arcs both of which use the path in a pressor manner although differently, but between two arcs that, though both of them control the path, control it differently, one in a pressor manner heightening its activity, the other in a depressor manner lowering or suppressing its activity.

I said that the scratch reflex is unilateral. If the right shoulder be stimulated, the right hind-leg scratches; if the left shoulder be stimulated, the left hind-leg scratches. If both shoulders be stimulated at the same time, one or the

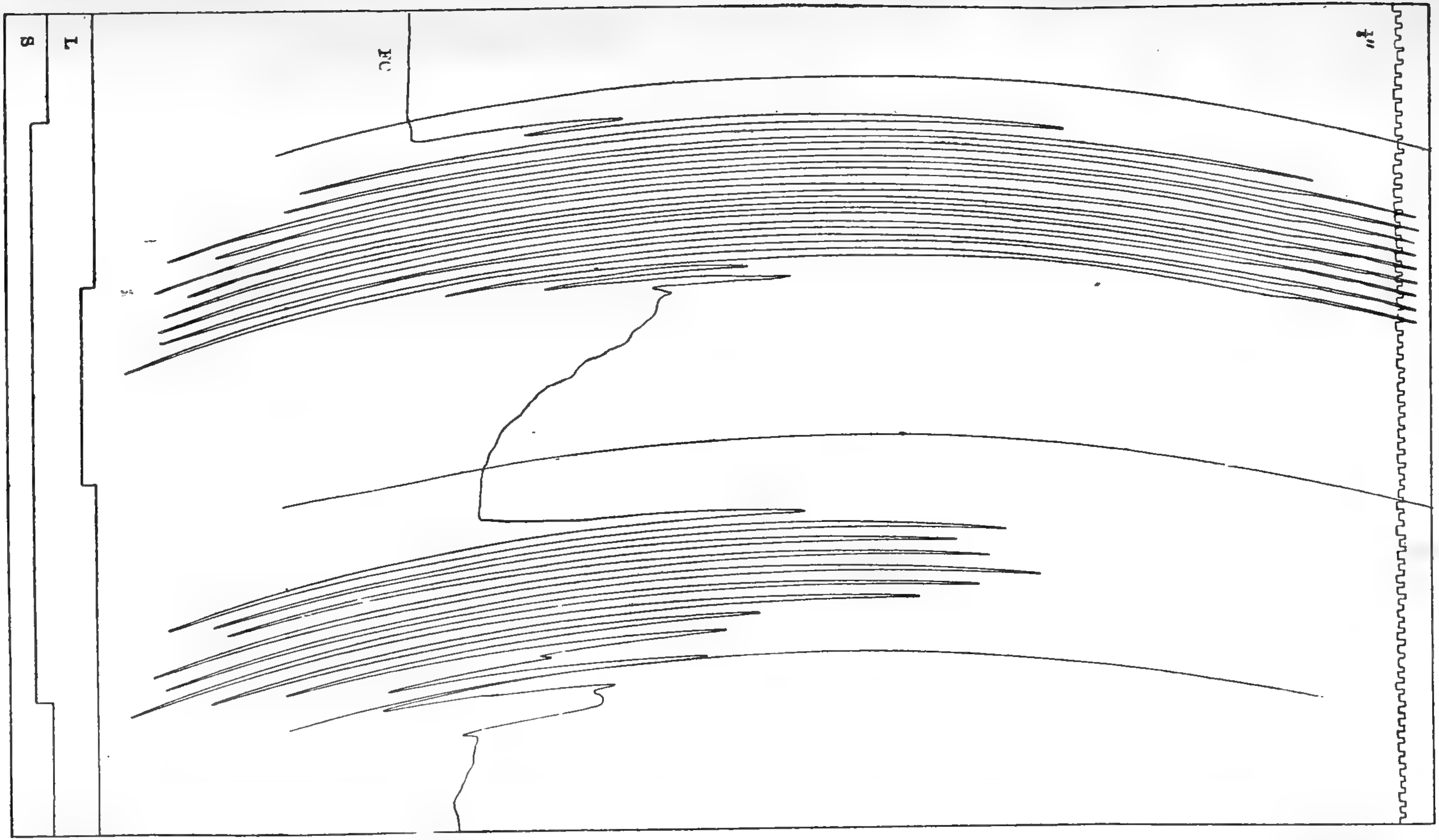
other leg scratches, but not the two together. The one reflex that takes place prevents the occurrence of the other. The reason is, that although the scratch reflex appears unilateral it is not strictly so. Suppose the left shoulder stimulated. The left leg then scratches. If the right leg is then examined it is found to present slight, steady extension with some abduction. This extension of the leg which accompanies the scratching movement of the opposite leg contributes to support the animal on three legs while it scratches with the fourth.

Suppose stimulation at the left shoulder evoking the scratching movement of the left leg, and the right shoulder then appropriately and strongly stimulated. This latter stimulus often inhibits the scratching movement in the opposite leg and starts it in its own. In other words, the stimulus at the right shoulder not only sets the flexor muscles of the leg of its own side into scratching action, but it inhibits the flexor muscles of the opposite leg. It throws into contraction the extensor muscles of that leg. In the previous example there was a similar co-ordination. The motor nerve to the flexor muscle is therefore under the control not only of the arcs of the scratch reflex from the homonymous shoulder, but of those from the crossed shoulder as well. But in regard to their influence upon this final common path, the arcs from the homonymous shoulder and the opposite shoulder are opposed. The influence of the latter depresses or suppresses activity in the common path.

Experiments by Verworn disallow any view that this kind of depression has its field in the motor nerve itself. Many circumstances connect it with the place where the converging neurones come together in the grey matter at commencement of the common path. The field of competition between the rival arcs seems to lie in the grey matter, where they impinge together upon the final or motor neurone. That is equivalent to saying that the essential seat of the phenomenon is the synapse between the motor neurone and the axone-terminals of the penultimate neurones that converge upon it. There some of these arcs drive the final path into one kind of action, others drive it into a different kind of action, and others again preclude it from being activated by the rest.

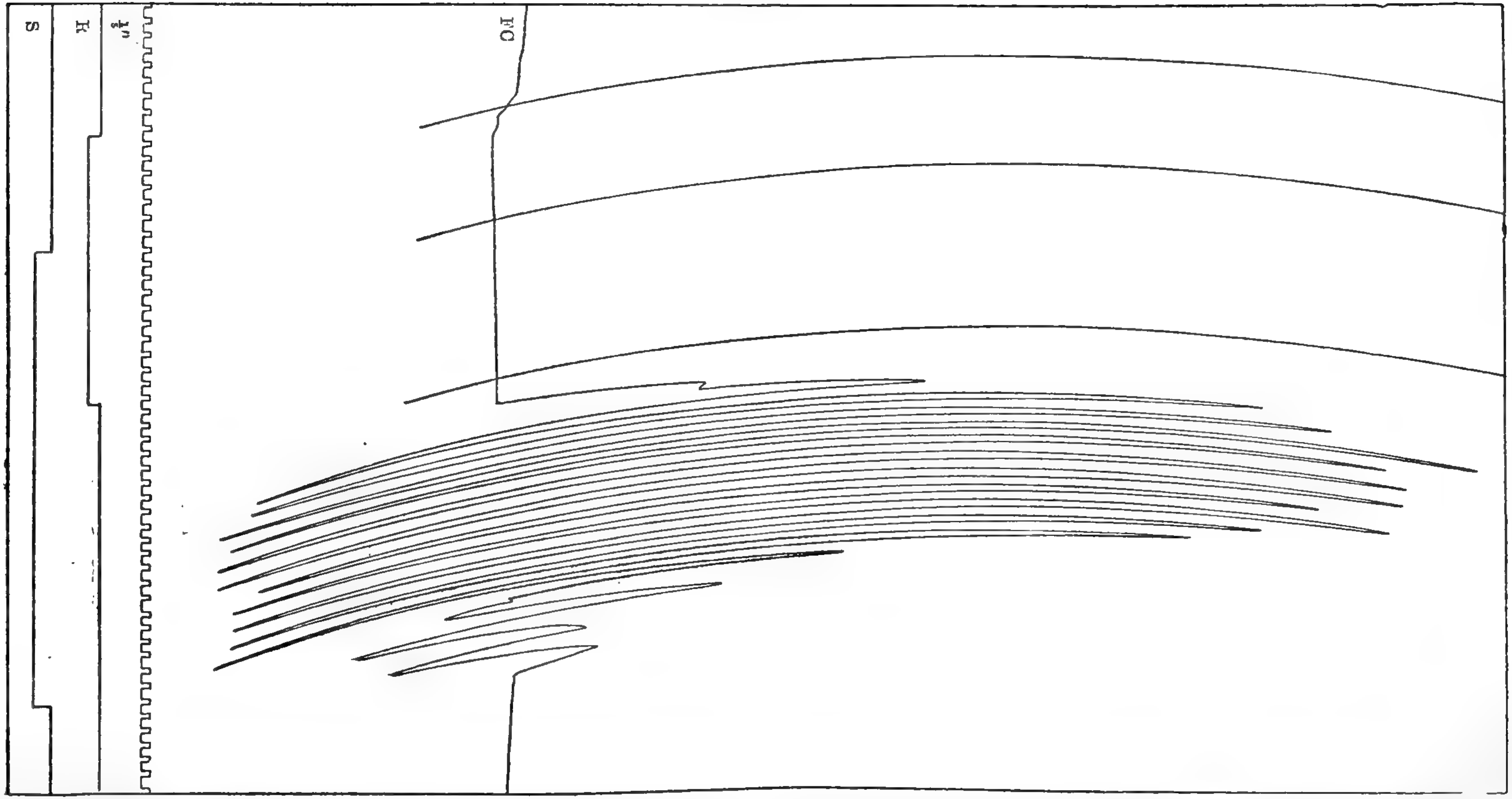
My diagram (fig. 1, B) treats the final common path as if it consisted of a single individual neurone. It is, of course, not so. The single neurone of the diagram stands for several thousands. It may be objected that in the various given actions these motor neurones are implicated in particular sets—one set in one action, one set in another. That view seems unlikely. In the scratch reflex, I think we can exclude it. The rhythm of that reflex has the same frequence whether it be excited strongly or feebly: thus, whether the extent of the contractions be great or small they recur with practically the same frequence. That a muscle contracts feebly under feeble stimulation of its nerve may be due in some cases to a fraction only of the nerve-fibres and muscle-fibres of the preparation being then active. But in the scratch reflex the whole group of motor neurones seem to act, even when the grade of contraction exhibited is quite weak. Let the reflex be excited by stimulation of the skin-point, sα (fig. 1 B), and let the stimulus be weak, producing only a feeble reflex. Then let another skin-point, sβ (fig. 1 B), be stimulated while sα is being stimulated, and let the stimuli at sβ be timed so as to fall alternately with those applied at sα. Then if the two paths impinge on two different sets of units in the compound group of motor neurones, evidence of two rhythms should appear, for the muscle-fibres can respond to a much quicker rhythm than the four per second. But in result the rhythm remains unquickened and unaltered. Either sα prevents the access of sβ to the motor neurones of FC, or sα's reflex having impressed its own tempo on the neurones of FC, the stimuli from sβ fall within a refractory period of the neuronic apparatus. On either supposition, sα and sβ must play upon the same individual neurones of the final path. A like result is given by all other points I have tried in the receptive field of the scratch reflex. Again, in the inhibitions previously mentioned, when there occurs the tonic contraction or the relaxation of the flexor we find no intermittent contraction of the scratch reflex grafted on them, as would be the case were that intermittent contraction still involving some part of the whole muscle. These

FIG. 2.



Interference between the reflex action of the left hip flexor, FC, caused by the nervous arc from the left foot (L, fig. 1 B) and the scratch reflex. The stimulation of the dorsal skin (fig. 1 A) inducing the scratch reflex began at the beginning of the notch in the signal line S, and continued throughout the period of that notch. Later, for the period marked by the notch in signal line L the stimulation of the foot was made. This latter stimulation interrupts the clonic scratch reflex in the manner shown. The time is registered above in fifths of seconds. The tracing reads from left to right. It is noteworthy that the interruption of the scratch reflex by the foot reflex is not established directly the foot-stimulus begins, and that it outlasts for a short time the application of the foot-stimulus.

FIG. 3.



Interference of the reflex from the skin of the opposite foot with the scratch reflex. FC, the flexor muscle of the left hip (fig. 1 B, FC). R, the signal line the notch in which marks the beginning, continuance, and conclusion of a skin stimulation of the right foot (fig. 1 B, R). S, signal line similarly marking the period of stimulation of the skin of the left shoulder (fig. 1 B, Sa). The ability of stimulus S to produce the scratch reflex takes effect only on concluding stimulus R; that is, S obtains connection with the *final common path* (the motor neurone of the flexor muscle) only on R's relinquishing it. Stimulus R, while excluding S from FC, causes slight contraction of FC's antagonist, and coincident slight relaxation of FC itself. Time in fifths of seconds. Read from left to right.

various reflexes seem to treat the final common path as a unit. The diagram therefore seems justified in representing the common path, FC, as a unit.

We have no time to multiply further now the categories of reflexes playing upon the final common path, FC. I might cite the deep reflex arc which arises in the muscles themselves and is answerable for the mild reflex tonus that even in the spinal animal maintains the tonic posture of the limb. Or, instead of having taken arcs that arise in the skin of the foot, we might have taken others arising above the knee, and traced a reflex influence different from the arcs arising in the foot, but yet playing upon the same final common path; or we might have taken arcs from the skin of the tail, that inhibit the reflex; or from the fore feet, or the ears.

There is, however, one instance of action upon this final common path, FC, which I would quote. Suppose, while the scratch reflex is being elicited from a point at the shoulder, a second point, say 10 centimetres distant, but also in the dorsal field of skin, is stimulated. The stimulation at this second point favours the reaction from the first point. This is well seen when the stimulus at each point is of subminimal intensity. The two stimuli, though each unable separately to invoke the reflex, do so when applied both together (fig. 4). This is not due to overlapping spread of the feeble currents about the stigmatic poles of the two circuits used. Mere cocainisation of either of the two skin-points annuls it. Moreover, it occurs when purely mechanical stimuli are used. It is evident that the arcs from the two points, *e.g.* sα and sβ (fig. 1 B), have such a mutual relation that reaction of one reinforces reaction of the other, as judged by the effect upon the *final common path*, FC. Such mutual reinforcement is usual between reflexes of identical species evoked from one and the same receptive field, *e.g.* the nociceptive of the foot.

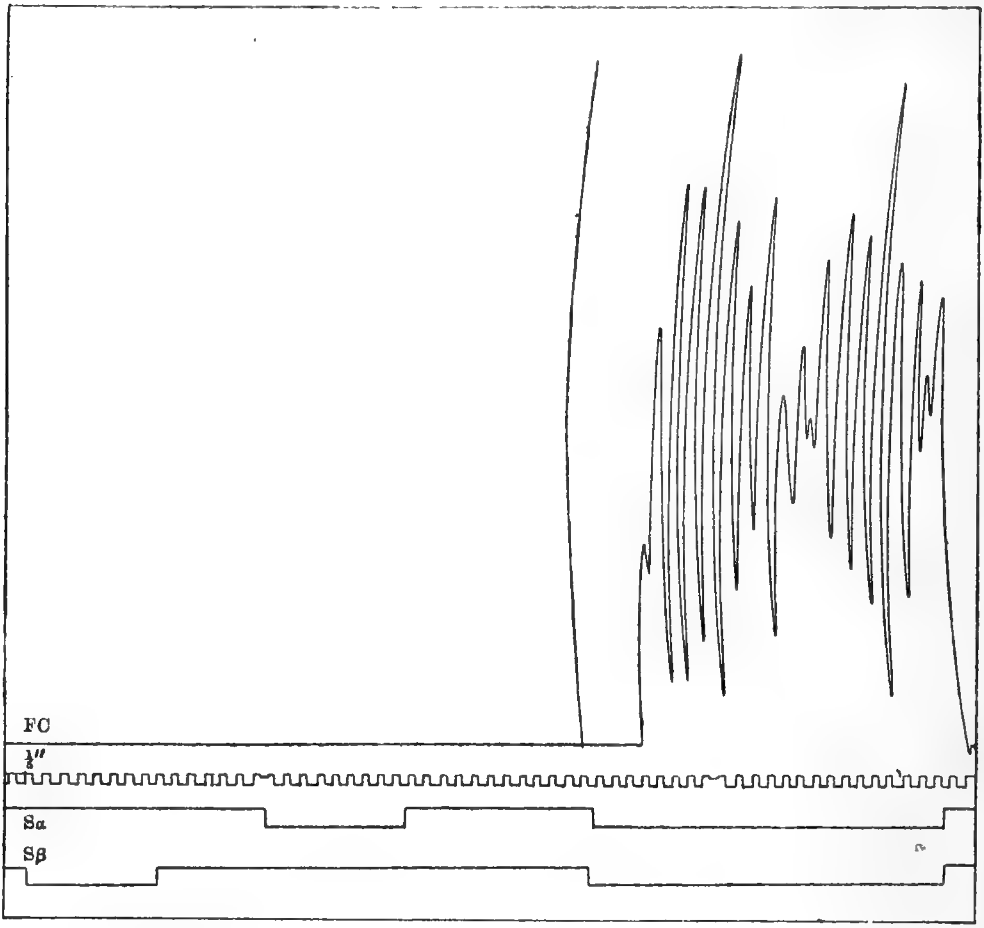
Not for all the arcs arising in the receptive field of the scratch reflex can, in my experience, this mutual reinforcement be demonstrated. There seems a gradual fall in reinforcing power as the distance between the receptors of the arcs increases. In this connection the following point is noteworthy. The scratch reflex carries the foot broadly toward the place of stimulation. In the spinal dog the reflex does not succeed in bringing the foot actually to the irritated point, yet when the irritation is far forward the foot is carried further forward, and when the irritation is far back the foot is carried further back. A scratch reflex evoked by a stimulus applied far back and high up in the dorsal skin is therefore not wholly like a scratch reflex evoked from far forward and low down. Now, the mutual reinforcement between the scratch reflex arcs in their action on the final common path, FC, seems greater the greater the likeness between the reflex actions they initiate. The coalition between the reflexes gradually decreases as the interval between their receptive points at the skin surface becomes wider. Whether coalition fades into mere indifference, or passes over into antagonism, my observations as yet do not say. But there are various receptive regions of the body surface that do, in the spinal dog, appear indifferent for the scratch reflex. Were it not that the nervous system is perforce mutilated in the 'spinal' animal, the number of these indifferent arcs might be fewer. In presence of the arcs of the great projicient receptors and the brain there can be few receptive points in the body whose activities are totally indifferent one to another. Correlation of the activities of arcs from receptive points widely apart is the crowning contribution of the brain toward the nervous integration of the individual.

In the case before us, then, the final common path—the motor neurone—to the hip flexor muscle is played upon by various categories of reflex spinal arcs. Of those mentioned, one category (i), the nociceptive from the leg itself, induces strong, steady contraction in the muscle. A second (ii), the scalptor or scratching from the dorsal skin, induces rhythmic contraction in the muscle. A third (iii), from the deep structures of the limb itself, induces the mild enduring contraction known as spinal tonus. A fourth (iv), *e.g.* the nociceptive from the opposite foot, depresses the activity of the muscle probably by excluding from it the activity of the other arcs which would excite the final path, the motor neurone. And there are many more we could trace from various regions of the body; also, pyramidal and other influences from brain for which our final path is likewise common. The arcs *within* one category may reinforce each other's action on the

common path, but those in separate categories are generally correlated in their action on their final common path in such a way as to antagonise one another. They are rivals for possession of their final common path, rivals as retinal points may be rivals for possession of the visual sensorium.

The extent to which in the nervous system this competition for possession of the common path obtains is very great. The multiplicity of the conflict seems extreme. The afferent fibres—that is, private paths—entering the central organ are much more numerous than are the final common paths. We owe to

FIG. 4.



Summation effect between the arcs Sα and Sβ of fig. 1 B. FC the flexor muscle of the hip. Sα the signal line marking the period of stimulation of the skin belonging to arc Sα (fig. 1 B) of the shoulder skin. The strength of stimulus is arranged to be subminimal, so that a reflex response in FC is not obtained. Sβ, the signal line marking the period of stimulation, also subminimal, of a point of shoulder skin 8 centimetres from Sα. Though the two stimuli applied separately are each unable to evoke the reflex, when applied contemporaneously they quickly evoke the reflex. The two arcs Sα and Sβ therefore reinforce one another in their action on the final common path FC. Time in fifths of seconds. Read from left to right.

Donaldson and his pupils enumerations which show that the afferent fibres entering the human spinal cord three times outnumber the efferent which leave it. Add the cranial nerves and the so-called optic nerves, and we may take the afferent fibres to be five times the greater. The receptor system bears therefore to the efferent paths a relation like the wide ingress

of a funnel to its narrow egress. The simile is bettered by supposing that within the general systemic funnel the conducting paths of each receptor may be represented as a funnel inverted, so that its wider end is more or less co-extensive with the whole plane of emergence of the final common paths. All these private paths converge in the nervous system to the great central organ, the spinal cord and brain, whence on the other hand all the final common paths irradiate. This central organ is, to return to our earlier metaphor, a vast network whose lines follow a certain pattern. But, as we see from the instances cited—more could be given abundantly, had we time—the pattern is unstable, the details of connection shift from moment to moment. We might compare the central organ with a telephone exchange, where from moment to moment the connections between starting and end points are changed to suit passing requirements. In order to realise the exchange at work, one has to add to its purely spatial plan the temporal datum that within certain limits the connections of the lines shift to and fro. The connections of any entrant path not only offer different degrees of resistance, but their resistances, both absolutely and relatively, vary from occasion to occasion. It is not merely that general conditions of nutrition, of blood-supply, &c., affect these resistances. The functional conductive activity of the nervous organ itself produces from moment to moment the temporary opening of some connections and the temporary closing of others. A good example is the 'reciprocal innervation' of antagonistic muscles—when one muscle of the antagonistic couple is thrown into action the other is thrown out of action. This is only a widely spread special case of a general principle. The general principle is the mutual interaction of arcs which embouch upon one and the same common path. Unlike arcs have successive use, but not simultaneous use of the common path. Like arcs mutually reinforce each other in their action on the common path. Expressed teleologically, the common path, although economically subservient for various purposes, is yet used only for one purpose at a time.

Thus the reaction initiated by one receptor while in progress excludes in various directions the reactions of other receptors. In this way the motor paths at any moment accord in a united pattern for harmonious synergy, co-operating for one effect. In the case of simple antagonistic muscles, and in the instances of simple spinal reflex arcs, the shifts of pattern of the conductive network from occasion to occasion are but of small extent. The co-ordination covers one limb or a pair of limbs. But the same principle extended to the reactions of the great arcs arising in the projicient receptor organs of the head, *e.g.* the eye, that deal with wide tracts of musculature as a whole, involves much further-reaching shift of the conductive pattern. The singleness of action from moment to moment thus assured is a keystone in the construction of the individual whose unity it is the specific office of the nervous system to perfect. Releasing forces acting on the brain from moment to moment shut out from activity whole regions of the nervous system, as they conversely call vast other regions into play. The interference of unlike arcs and the reinforcement of like arcs seem to lie at the very root of the great psychical process of 'attention.' I will not trench on psychological aspects of the problem.

I have urged that the struggle between dissimilar arcs for mastery over their final common path takes place in the *synaptic field* at origin of the final neurones. Mutual reinforcement by similar arcs seems also referable to the same synaptic field. As to the nature of the physiological processes involved, little, it appears to me, can be said. The final common path seems an instrument more or less passive in the hands of the various arcs that use it. Thus in the scratch reflex one arc can impress one rhythm on it, another another. And in 'fatigue' FC reveals, though it does not share, the failure of force of the tired arc playing on it. In regard to the reciprocal innervation of antagonistic muscles W. MacDougall has offered a suggestion of great interest, for which he obtains support from various sensual reactions. He suggests that the neurones of an antagonistic pair are so coupled that when one becomes active it drains energy from its fellow. This takes cognisance of the significant fact that central inhibition seems always accompanied by heightened activity at some related spot. Yet at certain times both the antagonists can

show high contemporaneous activity (strychnia, some forms of 'willed' action). I think, rather, that in some way the terminal of that arc which for the moment dominates the final common path, disconnects that path from all terminals dissimilar from itself.

Whatever be the nature of the physiological process in the conflict between the competing reflexes, the issue of that conflict—namely, the determination of which competing arc shall for the time being reign over the final common path—is largely conditioned by three factors. One of these is the relative intensity of the stimulation of the rival reflexes. An arc strongly stimulated is *cæteris paribus* more likely to capture the common path than one which is excited feebly. In the spinal dog, retraction equally induced in both legs mutually excludes the crossed extension of either side, but if unequally induced allows the crossed extension of the stronger reflex to exclude the weaker reflex altogether. The common path is probably never out of the grasp of some one or other reflex. Thus, in the spinal dog even, with its limb apparently at rest, this is true. The final common path of the extensor of the knee lies, then, in the hands of a tonic reflex arising in the muscle itself. Given a strong skin stimulus, and it passes under the mastery of the reflex arising in the stimulated skin; but when that is over, the tonus arc immediately repossesses it, and for a short time, as shown by the knee-jerk, more strongly than before.

A second main determinant for the issue of the conflict between the rival reflexes is the functional species of those reflexes. Arcs belonging to species of receptors which, considered as sense-organs, provoke strongly affective sensation—*e.g.* pain, sexual feeling, &c.—win the final common path with remarkable facility. Such reflexes override and set aside with peculiar potency reflexes belonging to touch organs, muscular sense-organs, &c. As the sensations evoked by these arcs—*e.g.* pains—exclude and dominate concurrent sensations in consciousness, so do the reflexes of these arcs prevail in the competition for possession of the common paths. They seem capable of pre-eminent intensity of action.

A third main factor deciding the conflict between the competing reflexes is 'fatigue.' An arc under long continuous stimulation of its receptor tends, even when it holds the common path, to retain its hold less well. Other arcs can then more readily dispossess it. A stimulus to a fresh arc has, in virtue of its mere freshness, a better chance of capturing the common path. The common path does not tire. In the scratch reflex under stimulation of sα, when the motor discharge becomes slow and irregular from fatigue, it is still perfect for sβ, or L, &c. (Fig. 1, B). This waning of a reflex under long-maintained excitation is one of the many phenomena that pass in physiology under the name 'fatigue.' Its place of incidence lies at the synapse. It seems a process elaborated and preserved in the selective evolution of the neural machinery. It prevents long continuous possession of a common path by any one reflex of considerable intensity. It favours the receptors taking turn about. It helps to ensure serial variety of reaction. The organism, to be successful in a million-sided environment, must in its reactions be many-sided. Were it not for such so-called 'fatigue,' an organism might, in regard to its receptivity, develop an eye, or an ear, or a mouth, or a hand or leg, but it would hardly develop the marvellous congeries of all those various sense-organs which it actually does.

But while talking of fatigue in general I forget the fatigue in particular of listeners. The principle I have tried to outline to you has many and wide applications; it seems fruitful for problems of Pathology and Psychology, as well as for those of Physiology. But I keep you too long. Let me sum up. The reflex arcs (of the synaptic system) converge in their course so as to impinge upon links possessed by whole varied groups in common—*common paths.* This arrangement culminates in the convergence of many separately arising arcs upon the efferent-root neurone. This neurone thus forms a final common path for many different reflex arcs and acts. It is responsive in various rhythm and intensity, and is relatively unfatigable. Of the different arcs which use it in common, each can do so exclusively in due succession, but *different* arcs cannot use it simultaneously. There is, therefore, interference between the actions of the arcs possessing the

common path, some reflexes excluding others and producing inhibitory phenomena, some reflexes reinforcing others and producing phenomena of 'bahnung.' Intensity of stimulation, species of reflex, fatigue, and freshness, all these are physiological factors influencing this interaction of the arcs—and under pathological conditions there are many others—*e.g.* 'shock,' toxins, &c. Hence follows successive interchange of the arcs that dominate one and the same final common path. We commonly hear a muscle—or other effector organ—spoken of as innervated by a certain nerve; it would be more correct as well as more luminous to speak of it as innervated by certain receptors; thus, the hip flexor, now by this piece of skin, now by that, by its own foot, by the opposite fore-foot, by the labyrinth, by its own muscle-spindles, by the eye, by the 'motor' cortex, &c. This temporal variability, wanting to the nerve-net system of medusoid and lower visceral life, in the *synaptic* system provides the organism with a mechanism for higher integration. It fits that system to synthesise from a mere collection of tissues and organs an individual animal. The animal mechanism is thus given solidarity by this principle which for each effector organ allows and regulates interchange of the arcs playing upon it, a principle which I would briefly term that of 'the interaction of reflexes about their common path.'

The following Papers were read:—

1. *On Reflex and Direct Response to Galvanic and Faradic Currents.* *By* Professor J. A. MacWilliam.

The author's experiments had proved that eels were remarkably responsive to electrical currents, a responsive fin movement of a reflex nature being readily elicited. The negative pole was usually the effective one. Frogs, newts, carp, &c., gave negative results. After death of the spinal cord much stronger currents were necessary to evoke any movement, and these were of a different character, being direct responses of the muscles.

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2. *On the Metabolism of Arginin.* *By* Professor W. H. Thompson, *M.D.*

If arginin, an important crystalline base obtained by the cleavage of proteids, is administered to animals, either by injection or with the food, from 80 per cent. to 90 per cent. of its nitrogen is excreted as urea. In the laboratory only 50 per cent. of the nitrogen can be split off from arginin as urea, the remainder appearing as ornithin. Hence in the body the ornithin nitrogen is also converted, largely or entirely, into urea.

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3. *On the Relation of Trypsinogen to Trypsin.* *By* Professor E. H. Starling, *F.R.S.*

Pawlow and his pupils have shown that fresh pancreatic juice, obtained from a pancreatic fistula, possesses no power of digesting proteids, but that after it has been acted upon by intestinal juice it gains that power. He concluded that the intestinal juice contained a ferment (enterokinase) which acted upon the trypsinogen of the fresh pancreatic juice, converting it into trypsin. Against this view French observers have brought forward another—viz., that the interaction of the two secretions is analogous to that of the cytases, and that the trypsinogen can only act upon proteids in the presence of enterokinase. Bayliss and Starling have studied the action of enterokinase upon trypsinogen, and by observing the rate of its action have, by finding that it follows the usual laws of ferment action, brought strong evidence to prove that Pawlow's view is the correct one, and that enterokinase is a 'ferment of ferments.' They have now further evidence in the same direction. By injecting rabbits with solutions of enterokinase they found that an antibody could be produced which, acting upon the enterokinase, was

able to inhibit its action upon trypsinogen. Although this in itself could not be regarded as definite proof, because the facts might bear another interpretation, yet, taken in conjunction with the former evidence, it was confirmatory of their view.

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4. *The Effect of Alcohol on the Heart.* *By* Dr. W. E. Dixon.

The author pointed out that much of the literature upon the subject was valueless, because the experiments had been conducted upon animals already under the influence of anæsthetics. The previous administration of chloroform or ether entirely abolished the first effects of alcohol. The experiments must, therefore, be conducted upon unanæsthetised animals or upon surviving organs. He proved that the first effect of alcohol upon the pulse was a slight acceleration, which he thought was due to an irritative effect of peripheral origin. The first action upon the heart was distinctly a stimulating one, as proved by cardiometer experiments. The effect upon the peripheral blood-vessels was a dilatation of the limb vessels, associated with a constriction of the vessels of the splanchnic area. The effect upon the blood-pressure was a preliminary rise, which was only converted into a fall when considerable doses had been given. If larger doses were suddenly administered, the effect upon the heart was usually marked inhibition, which he ascribed to a direct action of the drug upon the cardiac centre.

FRIDAY, AUGUST 19.

Discussion on Oxidation and Functional Activity. *Opened by* Sir J. S. Burdon Sanderson, *Bart., F.R.S.*

In undertaking to open this discussion I do not claim to contribute any results of my own researches or to speak on any subject *ex cathedra*, or with any degree of finality. I propose to state very shortly what seems to me the discussable questions, *i.e.*, those respecting which we have experimental data, and to submit to the Section those on which we need enlightenment.

The title is 'Oxidation and Functional Activity.' May I say that, without criticising it, I would ask for some latitude as regards the word oxidation? By oxidation is meant the formation of an oxide. Now we know that in the living organism oxygen may, and does, act without this happening; *e.g.*, in those processes of which the oxygenating of the colouring matter of the blood is the type.

This is so important a distinction that I would suggest to substitute in these cases the term 'oxygenation.' The subject of our discussion would then be rightly stated as follows: 'The Relation between Oxygen and the Chemical Processes which Constitute Animal and Plant Life.' The older notion of the part played by oxygen in the chemical processes of life was that it was a destroyer, and not a maintainer of the chemical energies of the cell. We now recognise that oxygen may have a double function to perform—first, as an element the presence of which is essential to the anabolic process by which living matter is built up; and, secondly, as equally essential to the disintegrative process, which, taking muscular activity as the type of others, is associated with the performance of function. Of these two actions, in each of which oxygen is concerned—the *con*structive and the *de*structive—the second is better understood than the first. It can be proved experimentally that in the living organism muscular work is accomplished by the transformation of a corresponding amount of chemical energy, however imperfectly we may understand how this transformation can occur at the temperature of the body. But as regards the participation of oxygen in the process of *restitution*, we are obliged to frame for ourselves a hypothesis and to clothe it in chemical language, according to which each elementary function is represented by a specific kind of living matter, *i.e.*, by an aggregate of *living molecules*, each of which is endowed

in equal degree with the capacity of discharging the function which it represents. The difficulty lies in this—that the physiologist finds himself compelled to use chemical language in a sense which the chemist does not recognise. What we mean thereby is that the hypothetical living molecule consists of a permanent part, which is not concerned in the performance of function, and of a collateral part, which is used, *i.e.*, disintegrated in every transition of the molecule from the inactive to the active state, to be immediately reconstituted when action ceases. This notion of *restitution* is the nutshell in which the difficulty lies. All that we know about it is that the access of oxygen is an essential condition for its accomplishment—oxygen not as an oxidiser, but as a restorer of functional capacity.

I now propose to pass from the general to the particular, *i.e.*, to the consideration of the chemical process of life as it presents itself in particular organs—namely, first in muscle and in nerve centre, and, secondly, in such glands as have up to this time been investigated—two groups of structures representing what Bichat called respectively animal life and organic life. On the general principle that in all our investigations we should proceed from the known to the unknown, muscle must be taken first, for its metabolism is more within reach of investigation and is better understood than that of any other organ.

When oxygen enters the living substance of muscle it is not as an oxidiser, but as a preparer and builder-up of material ready for explosion. For the muscle molecule receives two things from the blood, oxygen and oxidisable material; but these two do not combine as a mere result of juxtaposition or of encountering one another. As Ostwald says, 'Der freie Sauerstoff ist ein sehr träger Stoff,' at the temperature of the body. It cannot be brought into action in the living organism by a stimulus so long as it is in its free state. It must first become what Pflüger calls 'intramolecular,' and thereby change its Trägheit for mobility. The immediate effect of the access of oxygen is that the living substance of which it becomes a part becomes more susceptible to mechanical and electrical disturbance—*i.e.*, more excitable than it was before. It requires, so to speak, to be wound up so as to become capable of discharging its oxidising function when awakened by a stimulus. Dr. Fletcher's experiments, to which I will return later, show that the more perfect this preliminary anabolic process is, the more complete will be the catalysis.

You will, I think, agree with me that in different stages of the metabolic process which is associated with muscular function oxygen acts in different ways—at one time taking part in an integrating process, for which we might, perhaps, employ the word oxygenation; at another in a process of oxidation, the molecule in which this occurs retaining its existence notwithstanding the disintegration of its oxidisable part.

We have now to pass on to the question how oxygen takes part in the functional activity of the central nervous system. The only part of that system which is within reach of experimental investigation is the spinal cord. We have to consider in how far the results of investigations in the cord and in muscle agree or differ.

Let me say on the threshold that our knowledge is largely due to work recently done at Jena and Göttingen under the direction of (or in co-operation with) Professor Verworn. I must first ask your attention to the method.

More than thirty years ago Cohnheim taught us the use of a preparation which we used to call 'the salt frog,' in which the blood was replaced by physiological salt solution. He discovered that notwithstanding the defect of hæmoglobin, and consequently of oxygen, the chief functions of life could be carried on. With much more perfect methods Verworn has followed Cohnheim. The improvement consists in this—that the circulation is maintained by mechanical means, so that by varying the rate of flow and the percentage of oxygen in the liquid the supply of oxygen to the cord can be increased or diminished at will. The effect produced is judged of by the mechanical responses to reflex excitation, the indications given by which are rendered more delicate by the previous administration of a trace of strychnine. The first step in the experiment is to establish a normal state of things by the circulation of

salt solution which has been freely exposed to air or oxygen. Under these conditions the response to stimulation of the surface consists of a succession of brief tetani, each lasting two or three hundredths of a second. The next step is to substitute salt solution which has been deprived of oxygen, and to observe that the reflex centre is gradually paralysed, as indicated by the fact that single tetani have taken the place of the serial responses, and that on renewing the supply of oxygen the former state of things is restored; and, finally, that these changes may be repeated over and over again with the same result.

All of these facts come under the general statement that, while oxygen has no power of acting as a stimulus, it increases the excitability of the centre, enabling it when excited to discharge itself so completely that after the discharge it is wholly incapable of responding. It further shows that oxygen shortens the time required for restitution to the normal—reintegration following disintegration—anabolism following catabolism so immediately that they may almost be considered as simultaneous.

If we compare the behaviour of oxygen in the centre with its behaviour in the muscle, we shall find that they differ chiefly in one particular—namely, in their time-relations. In both cases oxygen acts as a predisposing, not as an exciting, cause of functional activity. In both cases a *tertium quid* is wanted—a liberating or letting-off mechanism; but in the muscle the functional cycle is accomplished in scarcely more than $\frac{1}{100}$ second, whereas in the centre the effect occupies a few hundredths of a second, and the preparation for it a much longer period. There is, therefore, no difficulty in understanding why the so-called refractory period can be so easily observed and measured in the centre (while in the muscle its presence can only be inferred), a circumstance which is helpful as affording an additional evidence of the anabolic action of oxygen; for it is easy to show that the period in question is shortened by supply of oxygen, protracted by its absence.

We now come to the last point which I am anxious to submit to you—that of the relation of oxygen to the function of glands. I must begin by saying that it is in this part of our subject that the crux lies, for the investigation of the intimate metabolism of glands is beset with difficulties even greater than those of muscle and spinal cord.

Mr. Barcroft, to whose admirable researches we shall have occasion to refer repeatedly to-day, found, as the result of his estimate of the oxygen and carbonic acid yielded by the blood circulating through the submaxillary gland under different conditions, that this gland takes from the blood much more oxygen when excited by the chorda tympani than when at rest, no such effect occurring when the excitation had been rendered ineffectual by the previous administration of atropine. These observations gave good reason for believing that oxygen promotes the action of the cells, but afforded no evidence that this action is attended by a corresponding discharge of carbon dioxide. Similarly, Professor Starling, whose experiments were made with Mr. Barcroft's co-operation, found that when the pancreas is made to act by the injection of secretin, a similar want of relation presented itself between the quantity of oxygen taken in and of carbon dioxide discharged. Finally, the comparison which has been recently made by Dr. Brodie (who will, I hope, explain to us his very admirable method) of the state of activity of the kidneys with the state of rest points to the same conclusion as regards that organ. When diuresis was produced by the injection of urea, the clearest evidence was given of the increased demand for oxygen, the intake of which was very largely increased, but there was no indication that the ultimate products of oxidation found their way into the blood in quantities proportionate to the oxygen supplied.

Taking these data as our point of departure, what can we infer from them as regards the resemblances and differences between the two processes we have been considering—viz., the functional activity of muscle and nerve centre on the one hand, that of gland on the other? The *obvious* contrasts which exist between secretion, muscular contraction, and reflex innervation need not be dwelt upon; the one thing with which we have to do is the nature of the chemical processes

which are associated with these three forms of activity. If analogies are to be sought for, it is here they will be found.

I submit to the Section, and particularly to those members of it who are engaged in experimental researches on the subject, that the most important contrast between the concomitant chemical processes of gland function and muscle function consists in this, that whereas the former is not in any marked degree catabolic, the dominant process in the oxidation which is inseparably associated with the performance of muscular function *is* catabolic. We can readily account for this by reference to the fact that whereas the processes in muscle and in reflex centre are excitatory, those in glands are for the most part determined by stimuli of a very different kind from those that evoke nervous or muscular action, which last act exclusively as liberators of catabolic processes which are waiting to be discharged.

We have long been accustomed to regard the process by which, in muscle, chemical is translated into mechanical energy as explosive and instantaneous, and to take the end result—the discharge of carbon dioxide—as the necessary concomitant of the production of heat and work; but, as I remarked before, Dr. Fletcher recently published experiments which seem to show that for the attainment of this ultimate result it is essential that the muscle should be abundantly supplied with oxygen, in failure of which the oxidation process may stop short before its completion. I trust that we shall have the advantage of hearing to-day the further results of his researches, and particularly that he will give us information as to the relation between efficiency of contraction and the degree of completeness of the oxidation process.

In conclusion, the questions which present themselves are :—

(1) Whether it may be generally stated that the oxygen which is conveyed to the living matter of the tissues by the blood *is stored as 'intramolecular oxygen' until it is required for the performance of catabolic functions*, and, if so, what is the *chemical relation* between the stored oxygen and the living molecules by which it is held? In submitting this question I must again ask that the use of the term 'living molecule' may be condoned.

(2) Whether it may be assumed that every *disintegrative process conditionates a subsequent integrative process*, by which the *status quo* is restored in the same living molecule; if so, does the anabolic effect which in muscle *follows* the change of form constitute as much a part of the response to stimulation as the catabolic effect which *precedes* the change of form? Can this be said of the chemical process which is associated with functional activity in gland?

Dr. W. M. Fletcher pointed out that in the muscle cell only the catabolic processes had been effectively studied, and that these are characteristic of the special material giving energy for contraction—a material probably without analogue in the gland cell. The classical conceptions, due to Pflüger and to Hermann, of this material as a highly oxygenated substance breaking down, whether rapidly as in contraction, or slowly as in survival periods, by inevitable stages to the ultimate stages of carbonic acid and water, irrespective of a contemporary supply of oxygen, were discussed and compared with the views of Verworn. It was urged that while a preliminary oxygenation of the living molecule may be admitted on wide grounds as the condition of irritability, such a conception by no means precludes the idea of additional oxidative processes occurring at some stage or stages of the catabolic disintegration. Disintegration effected under anaërobic conditions might, on this view, stop short of its normal end products, these being replaced by representatives of earlier stages in the breakdown. Evidence in this direction has been got from three main classes of experiment. In the case of excised muscle, Dr. Fletcher's observations of the relation of oxygen supply to the yield of carbonic acid in rest and in activity, and to the onset of fatigue and of rigor, were described, and held to be incompatible with the view that the entrance of oxygen conditioned the lability of the molecule without further influence upon the subsequent course of catabolism. A second class of evidence was derived from the work of Chauveau and Kauffman, Ludwig and his pupils, Minot and others, upon the respiration of muscles with artificial circulation. An

increased yield of carbonic acid due to activity was claimed or denied by these observers strikingly in proportion to the success with which the artificial circulation had been made to reproduce the normal. A third and large body of evidence is supplied by observers like Araki, Geppert, Meyer, and others, who have studied the results of muscular contraction with normal circulation, but under conditions of deficient oxidation. Anaërobic conditions always appear to diminish the amount of carbonic acid expired, while increasing the amount of acid products in the tissues, the blood, or the excreta.

The following letter from Professor Zuntz was read:—

'Berlin, August 1, 1904.

'Dear Sir,—I put off answering your letter of July 11 till to-day, because I was always hoping to be able to arrange to come to the meeting. Now I must, however, quite definitely give up all hope of this pleasure.

'I should like, however, to take the liberty of making some remarks on the questions, which I herewith return. Would you please read at the meeting just so many of these remarks as you think *à propos*?

'In the case of Nos. 1–4 I should like to suggest the following question. Is one justified in drawing a hard line between the anabolic and the katabolic processes on theoretical grounds? Would it not be more correct to take Pflüger's view ("Ueber die physiologische Verbrennung in den lebenden Organismen," *Pfl. Arch.* x.), and regard that process as the normal one, in which every katabolically decomposed molecule is at the very *moment of decomposition* anabolically regenerated by taking up oxygen and oxidisable groups? In this case one would regard the katabolic processes, which render the molecular structure less stable and give rise to free affinities, as the factor which inaugurates and makes possible normal anabolism. In this connection, however, the fact remains that anabolism can also take place later on if an element, such as oxygen, necessary to the building up of the molecule, should be wanting at the time that the katabolic processes occur. It is, accordingly, a subject for investigation to decide whether subsequent regenerative processes occurring in the above manner take place as easily as normal assimilation occurring at the same time as the breaking down of the molecule, or whether they use up more energy if they occur later.

'I have already some experimental data which would tend to show that *anabolism demands more energy if it has to take place at a period after the katabolic processes*, but I dare not yet give any definite verdict on the question.

'In the case of 5, I should like to lay stress on the fact that the fundamental importance of innervation for katabolic processes in muscle is not easy to reconcile with the assumption that these processes are much affected by enzymes. Neither does the great influence which the *tension* of a muscle has on oxidation processes in it harmonise with our knowledge of the action of enzymes. In the case of 7, you will permit me to refer to my observations on working men and animals which, to some extent in contradiction to many less recent results, have proved that under normal conditions of nourishment the respiratory quotient remains the same for rest and for work; a fact which tends to show that the same foods also are oxidised in *the same way* in both cases. (Compare 'Untersuchungen über den Stoffwechsel des Pferdes,' Berlin, 1898; 'Studien zur Physiologie des Marsches,' Berlin, 1901. *Pflüger's Arch.* 83, Heft 10–12.

'Part of the above I wrote as Question 8 on the enclosed sheet.

'With sincerest greetings, I am, yours truly,

'N. Zuntz.

Questions referred to in the above Letter.

1. Is the anabolic process accompanied by absorption of oxygen?
2. Is the anabolic process accompanied by evolution of CO_2?
3. Is the katabolic process accompanied by absorption of oxygen?
4. Is the katabolic process accompanied by evolution of CO_2?
5. How far is either of these processes the work of an oxidase?

6. To what extent are the respiratory phenomena of living tissues the same for all organs?

7. Are the respiratory processes of organs during activity different in kind, or only in degree, from those of resting organs?

8. [Does the anabolic process require a special amount of energy when it is not connected with the katabolic process? (ZUNTZ.)]

9. [Is there a difference between different carbohydrates with regard to their *immediate* action upon the metabolism, and does the condition of the body, viz., the amount of glycogen stored up in the body, account for this action? (JOHANNSON.)]

Professor T. G. Brodie described the results obtained in experiments, conducted in conjunction with Mr. Barcroft, upon the gaseous exchanges in the kidneys under the different conditions of rest and activity. In all cases they had found that the amount of oxygen taken in by a kidney which was made to secrete urine actively was greatly in excess of that absorbed by a resting kidney, while, on the other hand, the quantity of carbonic acid eliminated showed far slighter variations. In the greater number of their experiments they had found that the kidney at rest eliminated a greater volume of carbonic acid than it absorbed of oxygen. Their results thus indicated that the performance of work by the kidney was accompanied by an approximately proportional increase in the intake of oxygen, while the output of carbonic acid, although increased, was usually much less in amount. From the fact that the carbonic acid output was often in excess of the oxygen intake, it would seem that the final metabolic change, as evidenced by the carbonic acid output, was a more gradual process, though the results they had obtained, up to the present, did not warrant the conclusion that the carbonaceous waste products resulting from the activity of the tissue were confined to carbonic acid only.

Mr. J. Barcroft, in discussing the metabolism of glands generally, pointed out that there were three methods which had been used for the investigation of their gaseous metabolism. In the first an excised organ was kept in an enclosed space, and the surrounding air analysed. This method had been dealt with by Mr. Fletcher, who had pointed out that the method shed light on the catabolic phase of activity only. In the second method the general gaseous exchanges of the body were watched during states of rest and activity of the organ to be investigated. This, however, was inapplicable to the glands of the body on account of their small size. The third method was that of measuring the blood gases, combined with an estimation of the rate of flow of blood through the gland.

Three glands have been studied by this method up to the present—the submaxillary, the pancreas, and the kidney. In the submaxillary gland the problem was very complicated, since the blood became concentrated, losing a tenth of its water, or even more, and a considerable quantity of the carbonic acid left the gland in the secretion. After due allowance had been made for these disturbing factors, it appeared that the O intake and the CO_2 output were increased from three- to four-fold during stimulation of the chorda tympani nerve. As to how far these changes might be due to concomitant vascular changes was studied by examining the gaseous exchanges of an atropinised gland during stimulation of the chorda. It was found that this led to no increase in the amounts of O withdrawn, though an increased output of CO_2 was observed.

In the pancreas, which had been studied in conjunction with Professor Starling, there was often no increased flow of blood synchronously with a secretion following an injection of secretin. They invariably found an increased absorption of O. Usually this increase was considerable: thus, from eight comparisons the mean quantity of O taken up by the resting gland was 1·5 c.c. per minute, and by the active gland 5·5 c.c. per minute. These results were entirely in harmony with those brought forward by Professor Brodie for the kidney.

It seemed, then, that glandular activity was accompanied by a large and instantaneous consumption of O, but that it was not necessarily accompanied by an increased CO_2 output.

Another point indicated was the magnitude of the gaseous metabolism of glands. In the submaxillary and in the pancreas, when at rest, about 0·025 c.c. to 0·035 c.c. of O per minute per gram of gland substance was absorbed. In the kidney, Professor Brodie had given one instance in which the organ was using as much as one-fifth of the total quantity of O taken in by the lungs, and it was common to find the O consumption of the kidney during diuresis to amount to one-tenth of the total taken by the whole body.

Professor T. Clifford Allbutt suggested that the theories advanced as to the part played by oxygen offered some explanation of the fact, often experienced clinically, that the administration of oxygen gave relief to patients not only in cases where the heart and lungs were affected, but in many others also. He had long since given up the idea that oxygen was effective in these cases simply on account of the more favourable conditions under which the respiratory functions were placed. This was evidenced, for instance, by the tenacity with which the patients adhered to the treatment; for example, in cases of the vomiting of pregnancy, where its administration was often of great service.

Sir John Burdon Sanderson, in bringing the discussion to a close, remarked that it had been an exceedingly fruitful one, and none the less so because the points under discussion had not been settled, but were still under investigation. It seemed clear to him that oxygen played two parts in metabolic processes, one of which was prominent in muscle, and was responsible for the final oxidation of explosive material, while the other, which was more accentuated in glands, was akin to a building-up process, as it was involved in the elaboration of new material.

SATURDAY, AUGUST 20.

The following Papers were read:—

1. *The Spread of Plague. By* Dr. E. H. Hankin.

In accordance with our views on the origin of epidemics it is necessary to believe that the plague which appeared in Bombay in the autumn of 1896 was derived from some previously infected locality. Two such localities have been suggested. The most obvious suggestion is to the effect that it was derived from Hong Kong, which town had been the seat of a serious epidemic in 1894, and which in 1896 remained still infected. An alternative suggestion was put forward, in the Report of the German Plague Commission, to the effect that it was derived from Garhwal. The suggestion was to some extent substantiated by the fact mentioned in the Report in question that two thousand fakirs from Garhwal had arrived in Bombay, on their way to a pilgrimage at Nassik, shortly before the appearance of the disease. Plague is endemic in Garhwal (a district in the Himalaya Mountains), and this locality is, therefore, a possible source of infection. By conversation with a fakir who had attended the Nassik festival Mr. Hankin learnt that the Garhwal fakirs only visit Western India on occasions when the Nassik festival is being held. This festival is held regularly at twelve-yearly intervals.

It occurred to Mr. Hankin that if Garhwal was the source of the Bombay plague, by means of fakirs, it might also be the source of previous epidemics of plague in Western India. On counting backwards from 1896 by twelve-yearly intervals, one arrives at 1836, the date of the Pali plague, and at 1812, the date of the Gujerat plague. That is to say, of the eight occasions on which these fakirs visited Western India during the nineteenth century, on no less than three an outbreak of plague appeared. This fact may be regarded as strongly substantiating the suggestion of the German Plague Commission as to the origin of the Bombay outbreak. Further, it is stated by Forbes that the Pali plague originated in a village a few miles distant from the town of Pali shortly after the arrival of some wandering fakirs, and that it was preceded by a mortality among the rats. It

was pointed out that these three plagues of Western India had certain characters in common in which they differed from the majority of plagues in other parts of the world. First, they were characterised by their greater intensity and persistence; secondly, during the greater part of their course, at all events, they showed more virulence in villages than in towns; thirdly, they spread over the affected country, like a wave, from village to village, and showed but little tendency to travel along trade routes; fourthly, in each of the outbreaks the pneumonic form of the disease was frequently observed. The fact that these outbreaks resembled each other, and differed in general from outbreaks elsewhere, in the above characters accords with the idea that they have a common origin. One apparent exception, however, which is of great importance, must be described. This is the black death. So far as evidence goes this outbreak was distinguished by each of the characters that have been ascribed to Indian plagues. In order, therefore, to be able to hold that Indian plague is of Garhwal origin it is necessary to show that the black death may possibly have been derived from the same source.

The black death is known to have been imported into Europe from the town of Caffa, in the Crimea, where the Tartar army had been besieging some Italian merchants. According to an Arab historian, Aboel Mahasin, the plague was brought to the Tartar army from Tartary, where it was present in the year 1346, if not earlier. At that period trade in horses and merchandise existed between India and Tartary. It is therefore necessary to investigate whether a Nassik festival occurred shortly before that time, and whether it was accompanied by an outbreak of pestilence. At first sight a study of Indian history appeared to negative the suggestion. It is stated, however, in Elphinstone's 'History of India' that a rebellion broke out in Ma'bar in 1341, and that the army sent to suppress it was destroyed by plague. It appeared desirable to investigate this statement in detail. Counting back by twelve-yearly intervals, we arrive at 1344 as the year of a Nassik festival. In view of the great antiquity of Indian religious festivals, we are safe in assuming that in that year a number of fakirs emerged from Garhwal on their way to the sacred shrine. Ma'bar is situated on the Coromandel coast, on the Madras side of India, and one would expect that the army of the Emperor of Delhi would not march anywhere near to Nassik. But a contemporary history dealing with the conquest of Ma'bar, some thirty-five years previously, describes minutely the route then followed by the army. It appears to have lain through, or near, Nassik, and the soldiers must have marched along the same route as the fakirs for all the first part of their journey. It is further recorded that when the army was destroyed by pestilence the Emperor himself was attacked, and that when suffering from the disease he halted at Deogiri, a town close to Nassik. It appears from a contemporary history that the army originally sent in 1341 was insufficient for its purpose; that the Emperor returned for reinforcements at a time when a famine was raging in Delhi, and that it was these reinforcements that were destroyed by the pestilence. The date of the famine is given as 1344. This is also given as the date at which the campaign terminated, and at which the rebels recovered their independence. Thus we have evidence that a plague broke out near Nassik in the year 1344, at a time when Garhwal fakirs were present, and it is obvious that this plague may have been carried to Tartary in time to have been the precursor of the black death, which is first known to have been present there in the year 1346. Other suggestions as to the origin of the black death, as, for instance, that it came from China, or from the supposed endemic area in Mesopotamia, or from the then existing endemic area of the Levant, if not contradicted by known facts, are at least unsupported by any positive evidence.

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2. *Observations on the Senses of the Todas.* *By* W. H. R. Rivers, *M.D.*

The observations on the senses of the Todas were made by methods similar to those employed in the work of the Cambridge Anthropological Expedition to Torres Straits. The results are in general confirmatory of the main conclusions

reached by that expedition. The observations on Papuan and Toda seem to show that there is no marked difference between uncivilised and civilised races in purely sensory powers. Any superiority in the sensory and perceptual feats of the savage is probably due to his powers of observation and of drawing inferences based on familiarity with his surroundings.

When there are differences between Papuan, Toda, and European, the Toda occupies in general an intermediate position between the Papuan and European, just as he occupies an intermediate position between them in intellectual and cultural development.

The only striking feature which marks oft the Toda from the others is the great frequency of colour-blindness. Whereas this condition is absent or very rare in some savage races, the proportion of colour-blind individuals amounts to 12·8 per cent. among Toda males, as compared with about 4 per cent. in European races.

3. *Recent Development of Helmholtz's Theory of Hearing.* *By* Dr. C. S. Myers.

Dr. Myers alluded in the first place to Ebbinghaus's conception of an internodal vibration of the basilar fibres, and showed its value in providing a theoretical basis for the degree of relationship between the various musical intervals. Next he referred to the discovery of intertones (Zwischentöne) by Stumpf, and to their importance in determining the number of adjacent basilar fibres thrown into vibration by any simple tone, and in modifying the principle of specific nervous energy as applied to the ear. Schäfer's theory of the origin of subjective combination-tones was then described, and the difference between objective and subjective combination-tones was discussed. Lastly, he showed the great value of Helmholtz's theory in best explaining the known pathological phenomena of hearing, and suggested that the hair-cells rather than the basilar fibres might be the sympathetically vibrating end-organs. Such a modification involved the application of altered physical considerations to the organ of Corti, but appeared more rational and less difficult on the whole.

4. *Experimental Investigations on Memory. The Localisation of Remote Memories.* *By* Dr. N. Vaschide.

I have been engaged for several years in studying the mechanism of memory, and have tried several times to settle certain points in the psychology of this phenomenon, which is apparently so simple, but in reality just as complicated as the most complicated elements of thought. My researches date from 1896. This time I shall try to determine the origin of remote memories and their localisation.

My researches have been carried out on children, on normal subjects, and on a large number of people suffering from psychic ailments. I employed the usual methods for the determination of memory. In a first series of experiments I tried to make the subjects under investigation learn either verbally or visually a given number of syllables, of words, of phrases, &c., and in a second series I tried to present to them scenes or objects, &c., or to make them be present at scenes or in situations either accidental or premeditated. Then at more and more remote epochs of time I proceeded to ask the subjects what they remembered of the facts, and how they recalled them. In certain cases the subjects were conscious of the effort which they were making, and they were asked to pay great attention to their memory, because some time later they would be asked to recall things. Next I tried asking a certain number of other subjects how they recalled and by what mechanism they localised their memory of known social and historical facts, in order to see the mechanism of localisation of certain memories which we may have together at more or less remote epochs, which I wrote down definitely at the time on account of my experiments. I may add, in conclusion, about record-

ing and technique, that I analysed my own memories, and I tried to make clear to myself the question of the memories of childhood, a little fogged by the researches made on them.

The result of my researches seems to be that the localisation of remote or mediate memories—in other words, the processes of localisation, whilst taking account of conservation, reproduction, and recollection, elements of the memory—and also of the association of ideas, are carried out to a certain extent in a way slightly different from the processes of immediate localisation.

Direct localisation—that is to say, the proceeding which consists in fixing the place of a word in a series, the place of an event or of a fact, the place being assigned according to the knowledge of the memory itself, and without other motive than memory—plays a more important part and, at all events, a more certain one than in immediate localisations. There appears to be a close and intimate relation between memorising, between the fixing of memory and the reproduction at a remote epoch; the intensity of that image has made it appear spontaneously without the memory intervening or the association of ideas classifying it.

Localisation by association is apparently the most utilised by the subjects, but its results contradict one another: they form the basis of great discussions, and guide minds at least towards analogous trains of thought, especially on account of the elements connected together by circumstances and of neighbouring situations, so to speak. The landmarks are not clearly defined, but they are very numerous.

Mediate localisation without association plays an important part; the subject uses definite fixed landmarks, which fall into order in his mind without having recourse to association.

The localisation by the association of a feeling is to be noticed in the most remote memories, when the landmarks are not distinct and when the feeling of the intensity of the image is dulled, and, at most, like a subservient phenomenon, but always indefinite, utilised, however, as a directing idea.

To this mode of localisation can be opposed localisation by recollection; reason then comes in, and a long deliberation occurs which takes up all the attention of the subject. These are in our case *à posteriori* distinctions; there may be mistakes, and inquiries into the first recollections of childhood may form an exception. Localisation by reason is the only conscious form; it must be imposed on the attention of the subjects as a means of investigation, because, as I have already said, the processes of localisation are based on reason. The subject looks for his landmarks, he knows how to manipulate his images, and, above all, he tries to take advantage of this recollection and of the examination of his mind.

In one word, briefly to recapitulate my researches, remote and mediate memories are localised in time and space according to the same processes as immediate localisation, but with a slightly different mechanism. Memory and association of ideas play a secondary part, and the discovery of good landmarks is dictated principally by reason. Thus we have the existence of a spontaneous automatic cerebral localisation resulting from latent qualities and subservient to thought, which localisation acts and exists independently of images. The mechanism is certainly extremely complex, and I propose to discuss this subject in a work on memory.

MONDAY, AUGUST 22.

Discussion on Conduction and Structure in the Nerve-arc and Nerve Cell.

Professor J. N. Langley, in opening this discussion, said that he restricted himself to a consideration of the general scheme of structure and arrangement of the nervous system in vertebrates, and the broad relation of this scheme to nervous

functions. At present there are two main ideas of structure, one often called the neurone theory, according to which the nervous system is made up of a multitude of neurones or cells which have no connection with one another, and the fibrillar theory, according to which the nervous conducting part consists of minute fibrils joined together here and there into a network. Professor Langley argued that whatever view is taken of the structure of the nervous system, the facts of degeneration of nerves show that it is made up of a number of trophic units, and that the theory of trophic units held whether the unit consisted of one or of a hundred cells, and whether the units were in continuity with one another or only in contiguity.

A second point which seemed certain was that the properties of the central nervous system required for their explanation some structure not present in the peripheral nerves. This structure might be, in part, the nerve-endings of the trophic units, but in part it must be referred to the nerve-cells, which, in fact, consisted of different protoplasm from that of either nerve fibres or nerve-endings.

If the fibrillar theory were true, there were facts which showed that the fibrils must be different in different parts of their course. This was illustrated by the action of nicotine and of other poisons on the different parts of the nervous system. With this modification the fibrillar theory simply transferred to a part of the cell functions which were commonly supposed to belong to the whole. But it could not be regarded as certain that there were any fibrils at all in the nerve cell, for the microscopic appearances varied considerably according to the method of preparation.

A point which was much contested was the question whether the trophic units were continuous with one another or not. This point was not of great physiological importance, but physiological facts were best explained on the assumption that the units were contiguous but not continuous.

The last point considered was whether the unit consisted of a single cell or of many cells. The study of the development of nerves had led different observers to entirely opposite conclusions. Experimentally, the question was of interest in connection with the regeneration of nerves. Numerous surgeons had found new nerve fibres in the peripheral ends of cut nerves, but their observations failed to show that some central connection had not been established. In some recent experiments made by Professor Langley, in conjunction with Dr. Anderson, it was found that without a single exception the new fibres had become connected with the central nervous system. The balance of evidence was, then, against the occurrence of autogenic regeneration and in favour of the unit consisting of a single cell.

Dr. A. Hill said that he was entirely prepared to give his approval to the neurone theory as defined by Professor Langley, but he objected that this was merely a statement of the cell theory, and did not require the special title given to it by Waldeyer. He was inclined to think that the more light we gained on this subject the more should we find that Bethe's view was correct. Apathy has shown a network of neuro-fibrillæ in nerve cells of invertebrates. This network is easily shown, and is beyond all doubt a structure existing during life. In the spinal ganglion cells of vertebrates a somewhat similar appearance is obtainable. It was easy to make preparations of vertebrate nerve cells in which fibrillæ were indisputably present, but how far this appearance was due to reagents it was impossible to say; but there was a strong probability that the net arranged itself about an existing system of fibrils. The connecting-link appeared to him to be the 'thorns,' and it was a remarkable fact that the spacing of the thorns corresponded to the spacing of the pericellular network. Far as we were from being in a position to form a conclusion on this subject, it was not impossible that neuro-fibrillæ, Golgi's net, and thorns form a system of conducting fibrils of extreme tenuity and almost infinite complexity.

Professor Graham Kerr gave an account of the results of his researches on the development of the nerves in Lepidosiren. His first studies on the mode of growth of the nerves in these animals seemed all in favour of His's view that the nerves developed as outgrowths from the spinal system; but more extended

observations upon embryos in various stages of development led him to the conclusion that the fibres originated as strands of undifferentiated protoplasm extending between the neuroblasts of the spinal cord on the one hand and the developing myotonic cells on the other. At a somewhat later stage fibrillæ appeared in these strands, and still later a sheath was formed from mesoblastic tissue which surrounded and enclosed the group of fibrillæ. A more doubtful conclusion which might perhaps be drawn was that the original path was one along which impulses surged to and fro, and that consequent upon this use the fibrillary structure was developed as a more convenient substratum for the maintenance and extension of that function.

Dr. Mann pointed out that nerve cells might be theoretically in one of three states—viz., separate units, or continuous with one another, or at one time continuous and at another separate. In all embryos at a certain period the motor cells in the cord form a syncytium with scattered nuclei, an arrangement which later on becomes less and less marked, until in most cases the cells form separate units. Cells not derived from a common mother-cell are never in continuity. He pointed out that great care was needed in drawing conclusions from any preparations where such electrolytes as corrosive sublimate were used for purposes of fixation, inasmuch as all coagulation by electrolytes invariably leads to a very distinct fibrillar appearance. This is much less marked after the use of such non-electrolytes as osmium tetroxide or formaldehyde free from formic acid. At present, therefore, we are not in a position to make any assertions as to the existence or non-existence of fibrils in nerve cells or in tissues.

Dr. W. B. Hardy also directed attention to the treacherous nature of the evidence of fibres and networks in cells. A fibrillar structure can be produced from a perfectly homogeneous solution of egg-white by fixing it with the ordinary reagents and staining it in the usual way. Again, if a concentrated viscous solution of egg-white be stretched between two points and then treated with the ordinary fixing reagents, it can be shown that the fibrils produced in it run longitudinally, and are connected by less prominent ones which run transversely. These fibrils must, of course, be purely artificial.

Dr. H. K. Anderson emphasised the point that, though the neurones might be physically continuous, yet on the whole they must be trophically discontinuous. Experimenting upon very young animals, he had found that section of a postganglionic segment led to degenerative changes in the corresponding preganglionic segment. On the other hand, the converse was not true. As a further point against the view that the fibrillæ of a preganglionic segment were continued down into the postganglionic fibres, he pointed out that Langley had shown that the mode of termination of the preganglionic fibres in the sympathetic ganglia was not specific, since an ordinary motor nerve can be made to grow down to a sympathetic ganglion, and, terminating there in its own specific manner, could yet establish physiological continuity.

Dr. E. Overton pointed out that it had been proved that the presence of sodium ions was an essential condition for the physiological activity of both muscular and nervous tissues; and, in the second place, it had been shown that both sodium and calcium ions were essential for the proper action of nervous interconnections, thus tending to prove that some third substance intervened between the two units—*i.e.*, that there was discontinuity.

Dr. W. MacDougall argued that the fact that motor neurones could not conduct backwards was the best evidence of discontinuity. Upon the same hypothesis depended also the simplest explanation of another typical characteristic of nervous activity—the effect of summation of weak stimuli. Moreover, the 'law of nerve habit' was most difficult to explain, except on the assumption that there is some intermediate structure between successive nerve elements which offers a resistance to the transmission of impulses—a block, however, which can be overcome by the action of appropriate stimuli.

Professor Langley, in replying on the whole discussion, suggested, among other points, that the strands of material described by Dr. Kerr in the development of nerve fibres might be simply connecting structures along which the

nerve fibrillæ, *i.e.*, the true nerve-element, grew down from the developing neuroblast.

The following Papers were read:—

1. *On Methods of Artificial Respiration. By* Professor E. A. SCHÄFER, *F.R.S.*

It is essential that any method of artificial respiration which is to be employed with the view of resuscitating persons asphyxiated by drowning or otherwise should be simple in application and capable of producing an efficient exchange between the lungs and atmosphere. Artificial respiration may require to be performed by a single individual, and the muscular exertion needed should not be great. The methods (Silvester and Marshall Hall) which are commonly recommended for use in this country fulfil none of these conditions. They are troublesome and complicated and require a large amount of muscular exertion on the part of the operator. In addition to this they are inefficient, *i.e.*, they do not effect a sufficient exchange of air between the lungs and atmosphere. This should average between 4,000 and 5,000 cubic centimetres per minute. The proof of the first statement is to be found in the experience of anyone who has tried to perform artificial respiration by these methods; the proof of the second is contained in the data given in the table which accompanies this communication. A further convincing proof is to be found in the fact that it is impossible to maintain the respiratory exchanges of a normal individual who submits to allow himself to be 'respired' by either of these methods, *i.e.*, he is unable to refrain from himself actively respiring on account of the air-exchange being insufficient.

The only method of artificial respiration which is perfectly simple to apply, and which effects a sufficient exchange of air per minute, is that of intermittent pressure upon the lower part of the thorax. The introduction of this system, although it had been suggested by Erichsen and others, is due to Dr. B. Howard (1869). By Howard's method the patient in a case of drowning is first turned face downwards and the back is pressed upon two or three times to force out water from the lungs, after which he is turned face upwards. The operator is then directed to grasp the lower part of the chest and to press gradually forward with all his weight for three seconds, then with a push to jerk himself back and wait three seconds, repeating this eight to ten times a minute.

This method is simple, can be performed by one operator, and is fairly efficient so far as air-exchange is concerned (see table). The drawbacks are (1) that the tongue in the face-up position tends to fall back and block the passage of air through the pharynx; (2) that there is risk of rupturing the liver (which is enormously swollen in asphyxia); (3) that there is risk of breaking the ribs if the operator is heavy and powerful, and if the patient be advanced in years.

These drawbacks are avoided by keeping the patient in the face-down (or prone) position during the whole operation. The tongue then tends to fall forwards, and the weight of the operator's body being communicated through his hands, which are placed over the lower part of the back (lowest ribs), compresses the thorax and abdomen in such a way that the pressure is diffused over a considerable area, and is less localised than by the method described by Howard. This produces greater efficiency and reduces the risk of injury to ribs or viscera to a minimum. The muscular exertion required is only that needed to swing the upper part of the body backwards and forwards on the hands about twelve or thirteen times a minute, the operator kneeling by the side of or across the patient. The pressure is gradually applied and gradually released. The amount of air exchanged by this method per minute (see table) is greater than that yielded by any other which has been tried, and may even exceed the ordinary rate of exchange of the individual. It is perfectly simple and easy of application by boy, woman, or man. It ought therefore to be practised in cases in which artificial respiration is required, in preference to methods which are both complicated and inefficient.

Table showing the Amount of Air exchanged per Respiration and per Minute by various Methods, as well as under Natural Respiration, with the Subject Supine and Prone:—

Method	Amount of Air per Respiration	Amount of Air per Minute
Natural respiration: subject supine .	489 cub. cent.	6460 cub. cent.
" " " prone . .	422 " "	5240 " "
Traction with pressure: subject supine (Silvester method)	178 " "	2280 " "
Rolling with pressure (Marshall Hall method)	254 " "	3300 " "
Intermittent pressure: subject supine (Howard's method)	295 " "	4020 " "
Intermittent pressure: subject prone .	520 " "	6760 " "

2. *The Necessity of a Lantern Test as the Official Test for Colour Blindness. By* Dr. F. W. Edridge-Green.

The author described two cases, both naval lieutenants, which he had examined. In both instances the men passed the wool test, but failed when examined by the lantern test. These were selected because both had daily experience with coloured lights, and not with wools. He concluded that because a man can sort wools correctly it does not follow that he can distinguish between coloured lights. In the author's opinion many varieties of colour blindness may escape detection by the wool test.

TUESDAY, AUGUST 23.

The following Papers were read:—

1. *On Protamines. By* Professor A. Kossel *and* H. D. Dakin.

Formerly the current view on the structure of proteïds was that the differences between them were to be regarded as quite superficial. It was thought that the different proteïds were, for physiological purposes, interchangeable, so that one might without serious error substitute one proteïd substance for another. Such a view is no longer tenable, and we have now no right to conclude that the proteïd of muscle is equivalent as a source of energy with proteïds derived from milk or from maize. Their chemical constitutions are different, and as a consequence we must assume a corresponding difference in their properties. For example, the amount of arginine in different proteïds is very different. Some of the constituent groups are not found at all in certain proteïds; thus lysin is completely absent from the proteïds of corn and maize, which are soluble in alcohol. There are in addition proteïds in which the number of different groups is very small, as is the case with the protamines.

In this class we find only four or five out of the seventeen or eighteen atomic groups which occur in the majority of proteïds. On the other hand, in the conjugated proteïds we have proteïds that contain many very remarkable components, groups of the most diverse kind, which associate themselves with the already numerous components of the proteïd molecule, and so increase the complexity of the whole.

The protamines offer the simplest relations for investigation. One of these substances, salmin, which originates from the spermatozoa of salmon, has, when

treated with boiling dilute mineral acids, given us five atomic groups: (1) Urea; (2) diamidovalerianic acid (combined with urea to form arginine); (3) serine; (4) monoamidovalerianic acid; (5) pyrrolidincarboxylic acid. The relative proportions in which we have found these products of hydrolysis are approximate as follows:—Ten molecules diamidovalerianic acid, ten molecules urea, two molecules serine, one molecule monoamidovalerianic acid, two molecules pyrrolidincarbonic acid.

The composition of *clupeïn* (from the spermatozoa of herring) we have found to be complicated by the presence of alanine, in addition to the constituents of salmine, so that we have six atomic groups and not only five, as in the case of salmine.

On the other hand, scombrine, according to recent investigations carried out with Mr. H. D. Dakin, possesses an even simpler composition. In addition to urea and diamidovalerianic acid we find only alanine and pyrrolidincarboxylic acid.

Sturine, derived from the testes of the sturgeon, presents a different combination. In this protamine two diamido acids are present, namely, diamidovalerianic acid and diamidocaproic acid, the former being combined with urea. To this complex already consisting of five groups, still another, a heterocyclic group, histidine, remains to be added.

Among other members of this class of substances, which, however, are as yet incompletely investigated, are *cyclopterine*, which, in addition to urea and diamidovaleric acid, contains tyrosine and other monoamido acids, also *α*- and *β-cyprinine*, which, so far as they have been examined qualitatively, resemble the other protamines, but nevertheless offer certain points of difference.

The proteïds, in the ordinary sense of the word, differ mainly from the protamines in the increased proportion of monoamido acids. The different groups I have enumerated, leucine, tyrosine, alanine, serine, diamidocaproic acid, one or other of which only occurs in certain protamines, are all found combined in the same proteïd molecule, so that the complexity of molecule is extraordinarily great. This complexity is further increased by the addition of other groups, *e.g.*, dibasic acids, such as aspartic and glutamic acids, which are not present in the protamines.

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2. *The Metabolism of different Carbohydrates.* *By* Professor J. E. Johannson.

Professor Johannson's experiments dealt with the rate of excretion of carbonic acid following the administration of various carbohydrates, and were conducted upon man in a respiration chamber. He first showed that for a particular individual the rate of excretion was practically constant if taken some hours after a meal, and that this rate did not vary with differences in the previous diet nor at different periods of the year. If, then, an individual is given a quantity of a particular carbohydrate about eight hours after a meal, the amount of increase in CO_2 excreted is to be assigned to the food given. He showed in this way that an increase of CO_2 followed the administration of glucose, saccharose, or levulose, and that this increase, which amounted on the whole to from 8 per cent. to 20 per cent. of the total carbon given, began within the first half hour and lasted from two to three hours. The increase persisted longer after saccharose or levulose than after dextrose, and the total amount was greater. He further showed that the amount of the CO_2 surplus was in proportion to the amount of carbohydrate given, if this did not exceed 150 grams. The effect of a dose of sugar was greatly influenced by the previous state of nutrition of the person experimented upon. Thus, after a fasting period of forty hours the amount of carbon retained was much greater than after a ten hours' period. A further point of interest was that the amount and rate of destruction of the various sugars were not influenced by the performance of work. The two effects were additive, and did not interfere with one another.

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3. *Some Observations on Blood Pigments.* *By* P. P. Laidlaw, *B.A.*

Hoppe-Seyler was the first to notice that iron in hæmochromogen was unstable to dilute acids, but his statements were contradicted by other observers. There is, however, no doubt on the subject, as is very easily demonstrated; not only so, but reduced hæmoglobin presents the same peculiar instability of iron, yielding hæmatoporphyrin to diluted HCl in the cold without heat. The fact that oxygen renders the iron stable in oxy-pigments indicates that it is in relation to the iron.

The instability of the iron in hæmochromogen shows that hæmatoporphyrin is present in the hæmatin molecule, and is not a product of intramolecular change. This is absolutely proved from the fact that hæmatin may be reformed from hæmatoporphyrin.

Iron-free hæmatoporphyrin is warmed in ammoniacal solution on the water-bath, and Stokes' fluid added; on repeatedly reducing the mixture for an hour or so, hæmochromogen is formed. The spectroscopic characters are identical in the natural and artificial pigments. If pure pigment is used hydrazine hydrate is required to effect reduction to hæmochromogen in both, and in the presence of blood proteids ammonium sulphide is efficient in both natural and reformed hæmatin. The method of synthesis and the percentage of iron render it probable that hæmatin does not contain an acetyl group, but that it is a combination of two hæmatoporphyrin groups with one of iron.

The incineration figure for iron appears to be a little less than 1 per cent., identical with that calculated for a compound of this sort. Compare Nencki's views on the point.

Turacin, the naturally occurring pigment in the wing feathers of some of the plantain eaters, may be obtained from hæmatoporphyrin by boiling with cuprammonium solutions.

The spectra and physical characters are identical in natural and artificial pigments; both contain rather more than 7 per cent. of Cu.

A cobalt compound of hæmatoporphyrin may be obtained by boiling ammoniacal solutions of hæmatoporphyrin and corbaltamine. This substance presents absorption bands in the same place as oxyhæmoglobin, and will reduce to the spectrum of reduced hæmoglobin.

Bilirubin will not form an iron compound on the lines of the above hæmatin synthesis, but what I believe to be a copper compound is obtainable by boiling with cuprammonium solution, a green pigment changing to intense blue-purple on acidification. This may be used as a test for bile pigment. The solutions in acid and acid chloroform have characteristic spectra.

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4. *On the Distribution of Potassium in Animal and Vegetable Cells.* *By* Professor A. B. Macallum, *Ph.D.*

The continuation of the investigation on the distribution of potassium in cells has furnished the following results:—

1. Potassium is never diffused throughout protoplasm, but is always localised, either in the condition of a solution or in the form of a precipitate in what appears to be inert material.

2. It is always more abundant in vegetable than in animal protoplasm. The preponderance in the former is due to the greater accession of the element to vegetable structures, in solution in sap and other currents, and to the precipitation in the protoplasm of the potassium so carried which is thus rendered inert.

3. The nucleus is absolutely free from it, and so also are structures of nuclear origin (heads of spermatozoids, animal and vegetable), as well as the 'central body' of the cyanophyceæ, which is regarded by some cytologists as a nucleus.

4. Only one tissue element, the nerve cell and the axis cylinder (the neuron),

was found to be wholly free from potassium. The medulla, on the other hand, may contain considerable quantities of it irregularly distributed, and some may be found between the axon and the sheath.

5. The protoplasm of smooth muscle fibre is almost free from potassium, but the doubly refractive substance in the dim bands of striated muscle is rich in it.

6. The granular zone in ferment-forming cells (pancreas) is rich in potassium, while the remainder of the cytoplasm is free from it. When the granular area diminishes through secretion there is apparently a concurrent diminution in the potassium-holding area.

7. All dead and inert material in a living tissue becomes charged with potassium. This is particularly the case with intercellular material.

8. The intestinal epithelial cells in vertebrates and invertebrates excrete potassium.

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5. *Investigations on the Nutrition of Man.* *By* Professor W. O. Atwater.

The author gave an account of the inquiry regarding the food and nutrition of man which is carried out in the United States by authority of Congress. The work is done by co-operation between the Department of Agriculture and a large number of universities, experiment stations, and other organisations from Maine to California. The Federal Government devotes 20,000 dollars (4,000*l.*) a year to the enterprise. This is used mainly as aid to research, and is supplemented by grants of money and other aid from State Governments and other sources. The inquiry has three aspects—one very practical, another more purely scientific, and a third educational.

On the practical side, studies are made of the composition, the digestibility, and the nutritive values of food materials commonly used in the United States. This is done by chemical analyses and by actual experiments with men. Investigations are also made of the kinds, amounts, and costs of the food consumed by people of different classes and occupations in different parts of the country. The results throw valuable light upon the physiological, hygienic, and economic phases of the subject. At the same time experiments are made on various collateral topics, and thus information of the greatest usefulness is being acquired.

The more abstract scientific researches have to do with the transformations of matter and energy in the body, and consequently with the fundamental laws of nutrition. The experiments are made with men by use of the respiration calorimeter, an apparatus which serves to measure the changes which take place in the body with different diets and under different conditions, as, for instance, with physical or mental work or of rest. One very interesting result is the demonstration that the law of the conservation of energy obtains in the living body. Such purely scientific research is difficult and costly, but the speaker insisted earnestly upon its fundamental importance. These experiments show very clearly how the demands of the body for energy, for warmth, and work decide the needs for food. Taken in connection with the practical inquiries, they reveal much that was previously unknown regarding the uses of food and the adaptation of diet to health, purse, and welfare.

Numerous illustrations were given of the results of these inquiries. The average man on average diet digests and utilises about 96 per cent. of the material and 91 per cent. of the energy of his food, the rest being rejected in the excretory products; but the proportions thus utilised vary with the person, and still more with the food. The investigations bring out these differences in much detail.

The question of the nutritive values of bread made from ordinary white flour as compared with the whole wheat meal or brown flour, such as is used to make 'brown bread,' was considered. Chemical analysis shows that the bran which is removed in making the white flour contains considerable quanties of nitrogenous materials, and also of mineral matters, such as phosphates. A natural inference

is that when the miller removes the bran he takes out the most valuable part of the flour. But the analysis in the chemical laboratory is not the same as that in the human body. The digestive apparatus of man has not the power to utilise the bran, consequently, when we eat the meal from the whole wheat we digest the part which makes the white flour and reject most of the ingredients of the bran. Cattle and sheep can digest the bran; the miller is, therefore, right in selling the bran for fodder for stock, and the white flour bread for man. This last statement perhaps requires a slight qualification. A large number of experiments with healthy men show that the nitrogenous ingredients of the bran escape digestion when made into bread, so that 1 lb. of white flour furnishes more digestible material than 1 lb. of the whole wheat meal; but it may be that the body obtains more phosphates from the whole wheat. This last question is still under investigation. The present probability, however, is that the chief value of the bran is as a stimulant to digestion in some cases where peristaltic action or the secretion of digestive juices is enfeebled.

While Professor Atwater could hardly adopt the vegetarian theory of diet, he believed that the idea of the need of large amounts of meat is often greatly exaggerated.

The investigations emphasise the great importance of a liberal diet for people engaged in muscular labour. They make it clear that in many cases the food of the poor is inadequate for normal nourishment, and must remain so until they have larger incomes or cheaper food.

The investigations also bring out clearly the reasons why people with sedentary occupations need less food than those with more physical exercise. Mental labour differs from muscular labour in requiring much less material and energy for its support. In general, people with sedentary occupations have the larger, and those whose labour is manual the smaller, incomes. Thus it comes about that the well-to-do are apt to be overfed and the poor underfed.

The application of these principles to some of the economic questions of the day was emphasised. High value was placed upon the inquiries of Mr. Rowntree regarding the conditions of living of the labouring classes in York. Other investigations in England and Scotland were referred to, and the statements of Mr. Charles Booth, in his monumental work on 'Life and Labour in London,' regarding the need of such an inquiry in Great Britain were quoted with approval.

'Half the struggle of life is a struggle for food'; half the wages of the breadwinner are spent on the food for himself and his family. Little regard is paid to the relation between the real nutritive value of food and its cost. The poor man's money is worst spent in the market, the poor man's food is worst cooked and served at home; here it is emphatically true that 'To him that hath shall be given, and from him that hath not shall be taken away, even that which he hath.'

The importance of proper diet as an aid to temperance reform was emphasised. In countless cases in the United States—and he presumed the same was true in England—the home diet of the labouring classes is not what it should be, and the cooking and the serving of the food are the opposite of attractive. It is not strange that the people take to drink. One place to work against the evil of alcohol is at the table.

The educational aspect of the subject was also dwelt upon. The Federal and State Governments which support these inquiries, and the institutions and individuals who carry them on, lay great stress upon the distribution of the results among the people at large. Not only are the details printed in scientific memoirs, but the practical outcome is condensed in pamphlets and leaflets which the Government prints literally by the million, and distributes gratuitously. Copies of these publications were shown. Schools, from the lower grades to the universities, are introducing the subject into their curricula, and leading educators are coming to recognise that when such themes are treated in the true scientific spirit as revelations of natural law, and their significance and their connection with life and thought are explained, they are valuable both for mental discipline and

for daily use. It is not a lowering, but a broadening, of the ideal of education which thus makes these subjects in the best sense humanistic.

In closing, Professor Atwater urged the importance of such inquiries. He showed how they were already being actively pursued in the different countries of the world—in Europe, in Japan, and in the United States—and suggested that the time had come for the development of the science of the comparative nutrition of mankind.

WEDNESDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *Motor Localisation in the Lemur. By* Dr. W. PAGE MAY *and* Professor ELLIOT SMITH.

In this paper the authors showed the area stimulation of which produced movements on the opposite side of the body, and demonstrated that the sequence of representation of movement was in agreement with that of Sherrington and Grünbaum on the ape. The discussion on the homologies of a small sulcus which had previously been described as postcentral and precentral, but which is really central, as Elliot Smith, arguing merely from morphology, pointed out two years ago, was also cleared up.

The results of localisation in the dog obtained by Elliot Smith and Wilson, who have shown that the excitable area is limited anteriorly by the crucial sulcus, were described. This result was in harmony with the histological results of Cushing.

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2. *On Descending Thalamus Tracts. By* Dr. W. PAGE MAY.

The author discussed the results of previous workers on the optic thalamus, and described some experiments he had made on this subject. He showed that, following lesions in the thalamus, certain motor disturbances were produced, and that descending paths could be traced from the thalamus into the anterior and lateral columns of the spinal cord. He also showed photographs and specimens of a descending tract, hitherto undescribed, in the posterior columns of the cervical and dorsal cord. This extended downwards from the thalamic region, and occupied a position near the middle line at the anterior end of Goll's column. In rare cases fibres could be traced into the lowest portions of the spinal cord.

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3. *Joint-ill in Foals. By* Professor G. SIMS WOODHEAD, *M.D.*

This is an affection of especial importance to horse-breeders, in which, in addition to certain constitutional symptoms, marked stiffness and swelling make their appearance in the joints, while at a later stage abscesses form. Investigation of the cause of this disease proved it to be due to a micro-organism which gained admittance into the young animal through the cut end of the umbilical cord. From the practical point of view it was therefore evident that such precautions as are taken against septic infection in the case of the child at birth should also be taken in the case of the foal.

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4. *A Committee of Pathological Research. By* Dr. T. S. P. STRANGEWAYS.

Dr. Strangeways gave an account of a committee of pathological research which is being founded with the object of investigating some of the more important diseases the pathology of which is as yet undetermined. The

committee proposes to select some special disease and make an exhaustive study of it from all sides, a study which will last for two to three years. It is proposed to found a small hospital which shall be devoted entirely to cases of that disease during its period of study. The committee is to be a comprehensive one, and include all who will watch the course of the disease, or who will undertake research work on the subject. These will report to a central body, which will be responsible for the distribution of the collected facts and literature of the subject to those actively engaged in the work.

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5. *The Effect of Chloroform on the Heart. By* Professor C. S. Sherrington, *M.D., F.R.S., and* Miss S. C. M. Sowton.

This paper embodied the results of an investigation into the amount of chloroform which, when administered to the heart, can dangerously embarrass its action. For this inquiry the authors had adopted the method, gradually evolved of recent years, of keeping the excised heart of a mammal alive by perfusing its blood-vessels with warm nutrient solutions. The heart used by them was that of the cat. The beating of auricle and ventricle was recorded graphically. The effect of chloroform was examined by allowing the perfusing fluid—pure saline, serum, or blood, as the case might be—to be replaced by a similar fluid to which chloroform in known quantity had been added. When this was done the chloroform showed its effect, practically at once, by diminishing the amplitude of the beat without altering its rate. The amount of the diminution was proportionate, within limits, to the concentration of the solution of chloroform. When exhibited in saline solution, chloroform showed a depressant action even in a dilution of 1 part in 150,000 of the saline solution. The full amount of the depression caused by a given solution was rapidly reached—*e.g.*, in a minute—and then the continued administration of that solution caused no further depression, even if continued for half an hour at a time. That is to say, there is no cumulative action of the drug detectable in the isolated heart so perfused for a period of half an hour. On the contrary, there was generally evidence of a slight waning of the depression as the exhibition of the drug was uninterruptedly maintained. This tolerance was, however, quite evanescent, for on interrupting the perfusion with the chloroform solution, and then returning to it, the depression recurred in its original depth. On discontinuing the perfusion with chloroform solution and reverting to the chloroform-free fluid, the depression caused by the chloroform—unless the chloroform solution has been of great concentration—is extremely rapidly removed, even when the beat of the heart has been for many minutes practically abolished. This suggests the view that the effect of chloroform on the cardiac muscle is due to the formation of some easily dissociable compound between the chloroform and some active constituent of the tissue. It has been recently urged by Moore and Roaf that this constituent is a proteid, and in favour of this view is a further fact elicited in the present inquiry. On comparing the amount of depression of a chloroform solution of given concentration, in salt solution on the one hand and in blood on the other, it is found that the effect of that concentration in blood is much less than it is in salt solution. In other words, the effect of a chloroform solution of given concentration in blood is only equivalent to that of a solution barely one-twelfth as concentrated in salt solution. This can be explained by supposing that the salt solution, though it supports the beat of the heart, supports it less well than does blood; but the more important part of the explanation seems to be that the tension of the chloroform in the blood is much less than in the salt solution. In other words, the difference seems referable to some constituent of the blood taking up and holding, in a relatively inactive form, a considerable fraction of the chloroform added to it. The chloroform added distributes itself in that complex fluid according to a coefficient of partition. It is only what is left over, freely dissolved in it, which is available for acting on the heart tissue. Comparative estimations of the depressant effect in blood, serum,

and saline solution show that serum is intermediate between the other two, so that evidently the corpuscles contain, in large measure, a substance that combines with the chloroform.

6. *Report on the Metabolism of the Tissues.*—See Reports, p. 343.

7. *Second Report on the State of Solution of Proteids.*
See Reports, p. 341.

8. *Report on the Physiological Effects of Peptone and its Precursors.*
See Reports, p. 342.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION—FRANCIS DARWIN, M.A., M.B., F.R.S.

THURSDAY, AUGUST 18.

The President delivered the following address:—

On the Perception of the Force of Gravity by Plants.

WHEN I had the honour of addressing this Association at Cardiff as President of the mother-section from which ours has sprung by fission—I spoke of the mechanism of the curvatures commonly known as tropisms. To-day I propose to summarise the evidence—still far from complete—which may help us to form a conception of the mechanism of the stimulus which calls forth one of these movements—namely, geotropism. I have said that the evidence is incomplete, and perhaps I owe you an apology for devoting the time of this Section to an unsolved problem. But the making of theories is the romance of research; and I may say, in the words of Diana of the Crossways, who indeed spoke of romance, 'The young who avoid that region escape the title of fool at the cost of a celestial crown.' I am prepared for the risk in the hope that in not avoiding the region of hypothesis I shall at least be able to interest my hearers.

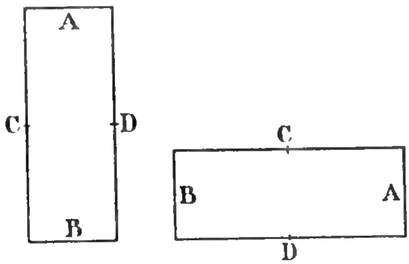
The modern idea of the behaviour of plants to their environment has been the growth of the last twenty-five years; though, as Pfeffer has shown, it was clearly stated in 1824 by Dutrochet, who conceived the movements of plants to be 'spontaneous'—*i.e.*, to be executed at the suggestion of changes in the environment, not as the direct and necessary result of such changes. I have been in the habit of expressing the same thought in other words, using the idea of a guide or signal, by the interpretation of which plants are able to make their way successfully through the difficulties of their surroundings. In the existence of the force of gravity we have one of the most striking features of the environment, and in the sensitiveness to gravity which exists in plants we have one of the most widespread cases of a plant reading a signal and directing its growth in relation to its perception. I use the word perception not of course to imply consciousness, but as a convenient form of expression for a form of irritability. It is as though the plant discovered from its sensitiveness to gravity the line of the earth's radius, and then chose a line of growth bearing a certain relation to the vertical line so discovered, either parallel to it or across it at various angles. This, the reaction or reply to the stimulus, is, in my judgment, an adaptive act forced on the species by the struggle for life. This point of view, which, as I regret to think, is not very fashionable, need not trouble us. We are not concerned with why the plant grows up into the air or down into the ground; we are only concerned with the question of how the plant perceives the existence of gravitation. Or, in other words, taking the reaction for granted, what is the nature of the stimulus? If a plant is beaten down by wind or by other causes into a horizontal position, what stimulative change is wrought in the body of the plant by this new posture?

It is conceivable in the case of a stem supported by one end and projecting freely in the air that the unaccustomed state of strain might act as a signal. The tissues on one side (the upper) are stretched, and they are compressed below; this might guide the plant; it might, in fact, have evolved the habit of rapid growth in the compressed side. This is only given as an illustration, for we know that the stimulus does not arise in this way, since such a plant, supported throughout its length, and, therefore, suffering no strain, is geotropically stimulated. The illustration is so far valuable, as it postulates a stimulus produced by weight, and we know from Knight's centrifugal experiment that weight is the governing factor in the conditions. Since we cannot believe that the stimulus arises from the strain as affecting the geotropic organ as a whole, we must seek for weight-effects in the individual cells of which the plant is built. We must, in fact, seek for weight-effects on the ectoplasm [1] of those cells which are sensitive to the stimulus of gravity.

If we imagine a plant consisting of a single apogeotropic cell we shall see that the hydrostatic pressure of the cell-contents might serve as a signal.

As long as the cell is vertical the hydrostatic pressure of the cell-sap upon the ectoplasm at C (fig. 1) is equal to that at D. But the pressure on the basal wall, B, differs from that at A (the apical wall) by the weight of the column AB. If the plant be forced into the horizontal, the pressure at A and B becomes the same, while the pressure at C no longer equals that at D, but differs by the weight of the column CD. Here undoubtedly is a possible means by which the plant could perceive that it was no longer vertical, and would have the means of distinguishing up from down. So that if it were an apogeotropic plant

FIG. 1.



it would need to develop the instinct of relatively accelerated growth on the side D, on which the pressure is greatest.

What is here roughly sketched is the groundwork of the theory of *graviperception* [2] suggested by Pfeffer [3] and supported by Czapek,[4] which I shall speak of as the radial pressure theory, and to which I shall return later.

It is obvious that there is another consideration to be taken into account, namely, that cells do not contain cell-sap only, but various bodies—nucleus, chloroplasts, crystals, &c.—and that these bodies, differing in specific gravity from the cell-sap, will exert pressure on the physically lower or physically higher cell-walls according as they are heavier or lighter than the cell-sap. Here we have the possibility of a sense-organ for verticality. As long as the stem is vertical and the apex upwards the heavy bodies rest on the basal wall, and the plant is not stimulated to curvature; but if placed horizontally, so that the heavy bodies rest on the lateral cell-walls, which are now horizontal, the plant *is* stimulated to curve. This is known as the *statolith theory*.

[1] See Noll's ingenious reasoning by which he makes it clear that the stationary ectoplasm, not the flowing endoplasm, is the seat of stimulation. Noll (88).

[2] I propose this term in place of *geoæsthesia*, which does not lend itself to the formation of adjectives, or the hybrid word *geoperception*. By not using the form 'geo' we avoid any necessary connection with geotropism, and may thus use terms compounded of *gravi* for phenomena other than those of curvature.

[3] Pfeffer (81). [4] Czapek (98), (01).

It seems to me quite certain that the stimulus must originate either in the weight of solid particles or in the weight of the fluid in the cells, or by both these means together. And for this reason. Take the statolith theory first. There undoubtedly are heavy bodies in cells; for instance, certain loose, movable starch-grains. Now, either these starch-grains are specialised to serve the purpose of graviperception or they are not. If they are so specialised, *cadit quæstio*; if they are not, there still remains this interesting point of view: the starch-grains fall to the lower end of the cells in which they occur; therefore, shortly before every geotropic curvature which has taken place since movable starch-grains came into existence, there has been a striking change in the position of these heavy cell-contents. Now, if we think of the evolution of geotropism as an adaptive manner of growth we must conceive plants growing vertically upwards and succeeding in life, others not so behaving, and consequently failing. There will be a severe struggle tending to pick out those plants which associated certain curvatures with certain preceding changes, and therefore it seems to me that, if movable starch-grains were originally in no way specialised as part of the machinery of graviperception, they would necessarily become an integral part of that machinery, since the act of geotropism would become adherent to or associated with the falling of the starch-grains.

This argument must in fairness be applied to any other physical conditions which constantly precede geotropic curvature; it is therefore not an argument in favour of the statolith theory alone, but equally for the pressure theory, and cannot help us to decide between the two points of view.

Are there any general considerations which can help us to decide for or against the statolith theory? I think there are—namely, (1) analogy with the graviperceptive organs of animals; (2) the specialisation and distribution of the falling bodies in plants.

(1) Berthold[1] (to whom the credit is due[2] of having first suggested that Dehnecke's falling starch-grains might function as originators of geotropic reaction) is perhaps somewhat bold in saying that 'the primary effect of gravity' as regards stimulation must depend on the passive sinking of the heavier parts. Noll, too,[3] says that Knight's experiment depends on weight, and not the weight of complete parts of the plant-body, but of weight within the irritable structure. I cannot see that these downright statements are justified on direct evidence, and I accordingly lay some stress on the support of zoological evidence. It has been conclusively proved by Kreidl's[4] beautiful experiment that in the Crustacean *Palæmon* the sense of verticality depends on the pressure of heavy bodies on the inside of cavities now known as statocysts, and formerly believed to be organs of hearing. The point of the experiment is that when the normal particles are replaced by fragments of iron the *Palæmon* reacts towards the attraction of a magnet precisely as it formerly reached towards gravity.

It is unfortunate that Noll's arguments in favour of the existence of a similar mechanism in plants were not at once followed by the demonstration of those easily visible falling bodies, which, in imitation more flattering than accurate, are called *statoliths,* after the bodies in the statocysts of animals. Personally I was convinced by Kreidl, as quoted by Noll, that here was the key to graviperception in plants. But it was not till the simultaneous appearance of Haberlandt's[5] and Němec's[6] papers that my belief became active, and this, I think, was the case with others. The whole incident is an instance of what my father says somewhere about the difficulty of analysing the act of belief. I find it impossible to help believing in the statolith theory, though I own to not being able to give a good account of the faith that is in me. It is a fair question whether the

[1] *Protoplasmamechanik,* 1886, p. 73. I was directed to this passage by Pfeffer's discussion (*Pflanzenphysiologie,* ed. 2, ii. p. 641).

[2] Berthold's remarks seem not to have received much notice, and it was not till the publication of Noll's *Heterogene Induction,* 1892, that a form of the statolith theory was at all widely recognised as a possible explanation.

[3] *Heterogene Induction,* p. 41.

[4] Kreidl (93).

[5] Haberlandt (00).

[6] Němec (00).

analogy drawn from animals gives any support to the theory for plants. The study of sense-organs in plants dates, I think, in its modern development, at least, from my father's work on root-tips, and on the light-perceiving apices of certain seedlings. And the work on the subject is all part of the wave of investigation into adaptations which followed the publication of the 'Origin of Species.' It is very appropriate that one of the two authors to whom we owe the practical working out of the statolith theory should also be one of the greatest living authorities on adaptation in plants. Haberlandt's work on sense-organs,[1] especially on the apparatus for the reception of contact stimuli, is applicable to our present case, since he has shown that the organs for intensifying the effect of contact are similar in the two kingdoms. No one supposes that the whisker of a cat and the sensitive papilla of a plant are phylogenetically connected. It is a case of what Ray Lankester called homoplastic resemblance. Necessity is the mother of invention, but invention is not infinitely varied, and the same need has led to similar apparatus in beings which have little more in common than that both are living organisms.

But, whether we are or are not affected in our belief by the general argument from analogy, we cannot neglect the important fact that Kreidl proves the possibility of gravisensitiveness depending on the possession of statoliths. We must add to this a very important consideration—namely, that we know from Němec's work[2] that an alteration in the position of the statoliths does stimulate the *statocyte.*[3] Such, at least, is, to my mind, the only conclusion to be drawn from the remarkable accumulation of protoplasm which occurs, for instance, on the basal wall of a normally vertical cell when that wall is cleared of statoliths by temporary horizontality. The fact that a visible disturbance in the plasmic contents of the statocyte follows the disturbance of the starch-grains seems to me a valuable contribution to the evidence.

There is one other set of facts of sufficiently general interest to find a place in this section. I mean Haberlandt's result,[4] also independently arrived at by myself, that when a plant is placed horizontally and rapidly shaken up and down in a vertical plane the gravistimulus is increased. This is readily comprehensible on the statolith theory, since we can imagine the starch-grains would give a greater stimulus if made to vibrate on one of the lateral walls, or if forced into the protoplasm, as Haberlandt supposes. I do not see that the difference in the pressure of the cell-sap on the upper and lower walls (*i.e.*, the lateral walls morphologically considered) would be increased. It would, I imagine, be rendered uneven; but the average difference would remain the same. But in the case of the starch-grains an obvious new feature is introduced by exchanging a stationary condition for one of movement. And though I speak with hesitation on such a point, I am inclined to see in Haberlandt's and my own experiments a means of distinguishing between the pressure and statolith theories. Noll,[5] however, considers that the shaking method is not essentially different from that of Knight's experiment, and adds that the result might have been foreseen.

Distribution.

As far as I know, the development of *statoplasts*[6] has not been made out. Are they at first like ordinary immovable amyloplasts; and, if so, by what precise process do they become movable? Where the two forms of starch are seen in close juxtaposition the difference between them is striking, and it is hardly possible to doubt that these differently situated bodies have different functions. In a seedling *Phalaris canariensis* the apical part has only falling starch-grains, while lower down both forms occur. It suggests a corresponding distribution of

[1] Haberlandt (01). [2] Němec (01, p. 153).
[3] *Id est*, the cells containing statoliths.
[4] Haberlandt (03) and F. Darwin (03).
[5] Noll (03, p. 131.)
[6] I would suggest the word *statoplast* in place of the cumbersome expression *movable starch-grains.*

graviperception; and, as a fact, the seedling is gravisensitive throughout, but is especially so at the apex. If this is not the meaning of the statoplasts we must find some other. For instance, are the loose starch-grains connected in an unknown way with heliotropic sensitiveness, which often has the same distribution as that of graviperception? Or is the looseness of starch connected in some way with food storage? Is it to allow of starch being closely packed in part of the cell, leaving the rest of the space free?

Again, the most striking general fact about the distribution of falling starch is its presence in the endodermis.[1] If we believe that the endodermis is essentially a tissue of gravisensitive cells we can understand the striking fact that it contains loose starch only as long as the stem is capable of growth curvature.[2] Otherwise, the theories of the function of the endoderm, which have never been very satisfactory, have the additional burthen of explaining this last-named fact.

According to Haberlandt (00), some monocotyledons whose leaves contain no starch have falling grains in the endodermis. Němec (01, p. 24) quotes from Sachs the case of *Allium cepa,* where statoplasts occur in the root-cap, the endoderm, and punctum of the seedling, and not elsewhere. Then we have occurrence of starch in the pulvinus of grasses and not in the rest of the haulm. *Viscum* is not geotropic, and has no statoplasts. In the holdfast roots of *Hedera* and *Marcgravia* there is no starch, and in *Hoya, Pothos,* and *Ficus* the starch is not movable, and these roots are not geotropic.[3]

Jost (02) brought forward, as a serious objection to the statolith theory, the fact that tertiary roots possess statoliths, but are not sensitive to gravitation. This objection has been overcome by the discovery [4] that when the primary root is cut off and a secondary assumes its place and manner of growth, the tertiaries springing from it are diageotropic, and thus have at least an occasional use for their statoplasts.

I have shown [5] that the cotyledon of *Setaria* and *Sorghum* is the seat of graviperception, and it is there that the statoplasts are found.[6] Wiesner (02) was unable to find statoliths in the perianth-segments of *Clivia nobilis,* which are geotropic, nor in those of *Clivia miniata,* which are not geotropic. Here would seem to be a serious objection to the statolith theory, but Němec (04, p. 58), on repeating Wiesner's observations, finds, on the contrary, a confirmation of his own views. For movable starch-grains occur in the perianth of *C. nobilis,* but not in those of *C. miniata.* In the case of roots the distribution of the statoplasts is especially worthy of note. Physiologists have gradually come to believe that my father [7] was right in his view that the organ of graviperception is in the tip of the root; and it is there—generally in the root-cap—and there only, that statoplasts are found. But these facts do not entirely harmonise with the statolith theory, as I shall show later on in the section devoted to experimental evidence. Here I will only add that the group of statocytes in the root are strongly suggestive of some special function, and those who deny that they form an organ of

[1] See Haberlandt (03) for a description of certain special cases of statocyte tissue, apparently replacing the endodermis.

[2] According to Haberlandt (03, p. 451), it is easy to be deceived in asserting that the endoderm contains no starch. Thus Fischer failed to find it in outgrown stems of some plants which possess it when young. Tondera (03) asserts that in certain Cucurbits the falling starch is only present in the older parts no longer capable of geotropism. But Miss Pertz, who has examined most of the species investigated by Tondera, finds statoplasts in the young parts where he failed to find these. Tondera makes some interesting remarks on the distribution of starch in the Cucurbits harmonising with Heine's storehouse theory. It is obviously difficult in the case of the endoderm to distinguish between starch serving as a reserve and starch serving as part of the mechanism of perception. I see no reason why the second function should not be evolved from the first.

[3] Haberlandt (03, p. 461).

[4] Darwin and Pertz (04).

[5] F. Darwin (99).

[6] According to Němec they occur to some extent in the hypocotyl of *Panicum.*

[7] C. Darwin (*Power of Movement*).

graviperception must find some other use for them; and this will be no easy task. I must not omit to mention the ingenious experiments of Piccard (04), which prove (if they prove anything) that the root-tip is not the seat of the graviperception, but that this quality is found in even greater perfection in the growing region of the root. But until the whole of the other experimental evidence is proved to be illusory, I must suspend judgment on Piccard's results and treat the question provisionally from our previous standpoint.

The existence of statoliths in regions which have ceased to be capable of ordinary geotropic curvature is at first sight a difficulty. Thus Miss Pertz has found in the pith of the watercress (*Nasturtium officinale*) the most perfect statoplasts, and this in winter, when the capacity for geotropic curvature was probably absent. Again, she has found movable starch in the xylem elements and in the cortex of a number of trees. In this case we must remember that, according to Meischke (99), Jost (01), and Baranetzky (01), woody branches of several years' growth are capable of geotropic curvature. If so, graviperceptive organs must exist. We must remember, too, that in the regeneration of cuttings Vöchting (78) has shown that gravitation has an influence in certain cases; such cuttings must therefore have organs of graviperception. Or, if this is not granted as necessary, it seems to me conceivable that falling starch-grains, though made use of, and in a certain sense specialised, for graviperception, should nevertheless exist and serve other purposes in the economy of the plant. But this question needs further detailed work.

Lastly, as part of the general question of distribution, it must be clearly pointed out that in a large number of plants, such as Algæ and Fungi, no statoliths are known to exist, though their complete absence has not been proved.[1] Here we must either believe in Noll's minute and hitherto unseen statoliths or in a different mechanism, such as hydrostatic pressure. There is no more impossibility in this state of things than in the presence of statoliths in *Palæmon* and their absence in higher animals. And I am glad to note that both Pfeffer and Czapek are not disinclined to believe in the possibility of various forms of graviperception.

Experimental Evidence.

A flaw runs through a great part of the experimental evidence, which may be illustrated by an experience of my own. I found[2] that seedlings of *Setaria* and *Sorghum* could be nearly deprived of statoplasts by means of a high temperature, and, further, that such destarched plants were markedly less geotropic than normal specimens. Here seemed a proof of the theory; unfortunately, however, it turned out that the plants in question were also rendered less heliotropic. These facts make it impossible to allow Němec's gypsum experiment to be convincing. He caused a loss of starch by inclosing roots in plaster of Paris, and found that they had in great part lost their geotropic power. But he did not discover whether this loss depended on disappearance of part of the sense-organ or on general loss of curving power, though he has since (02) made the interesting observation that roots so treated are capable of hydrotropism. Again, Němec found in resting seeds of *Vicia Faba* that the statoliths are undeveloped, and that they appear synchronously with the power of geotroping. Would not a similar thing be true of the apheliotropism of *Sinapis* roots—*i.e.*, might it not be found that they were not heliotropic until the starch appeared?

The same objection must be brought against Haberlandt's otherwise convincing observation[3] that *Linum* growing out of doors in late autumn or winter is both devoid of statoplasts and incapable of geotropism, and that the power of

[1] See Němec (*Beihefte Bot. Central.*, B. xvii., 1904, p. 59), where he describes the cases and the occurrence of statoliths in the mosses and liverworts. Giesenhagen (01) has described heavy bodies at the tips of the rhizoids of *Chara* which fall to the physically lower side.

[2] F. Darwin (03).

[3] Haberlandt (03). It seems, however, that the starchless plants had some heliotropic capacity.

curvature returns on bringing the plants indoors, when the starch reappears. The full value of these experiments cannot be made clear without going into more detail than is here admissible. They are particularly interesting because, as Haberlandt remarks, so far as they prove the truth of the statolith theory, they also disprove the pressure theory. This may also be said of other experiments mentioned in the present section.

We must, I think, object on similar grounds to Němec's observations, suggestive though they are, on the absence of geotropism in certain individual leaves and roots which, through unknown causes, had no statoliths.[1]

The same must be said of the above-mentioned experiments of Haberlandt, in which geotropism is increased by rapid shaking in a vertical plane. I attempted[2] to avoid this fault in the similar experiments with a tuning-fork made independently, which showed that the effect of vibration in increasing reaction is far greater in the case of geotropism than in heliotropism.

Haberlandt (00) made the interesting observation that plants deprived of their endodermis by means of an operation lose the capacity of geotropism. Here, again, we ought to know how the operation affects sensitiveness other than geotropic; and, as Haberlandt grants, it may perhaps be said that the operation is too serious to allow of the foundation on it of a very convincing argument.

The question how far the statolith theory is applicable to the root is a difficult one. It involves the old and apparently insoluble difficulty of distinguishing between the removal of the tip of the root, considered as a perceptive organ, and the effect of the shock of the operation. The question is, moreover, complicated by contradictory evidence. According to Czapek, cutting off a small part of the root-tip, an operation which does not remove the whole of the statoliths, interferes with geotropism in the same way as does actual amputation.[3]

Němec, on the other hand, finds evidence for the operation depending on the removal of the sense-organ; for according to him the power of geotroping does not return with the appearance of *general* symptoms of recovery, such as cell division and the growth of a callus, but only with the actual reappearance of statocytes.

Němec's most recent experiments[4] are confirmatory of this result. He finds that Lupin roots, from which $\frac{1}{2}$ mm., 1 mm., and $1\frac{1}{2}$ mm. respectively are cut off, behave differently. The $\frac{1}{2}$ mm. lot were clearly geotropic in seven hours, while no curvature occurred in the others. After a further interval of thirteen hours the 1 mm. lot had curved. Microscopic examination showed that statoplasts had appeared in these roots, but not in the $1\frac{1}{2}$ mm. lot, which showed no geotropism. It is particularly interesting that according to Němec the statoplasts appeared in a new growth which was visible as a slight convexity of the cut surface.[5]

An experiment by Němec with the roots of *V. Faba* must also be mentioned. One millimeter was cut from the tips of each of a number of roots, and they were all placed horizontally. They were examined after fifteen hours, when considerable variety in the result of the operation was evident; some of the roots had bent geotropically, while others were still horizontal. On cutting sections it was found that the geotropic roots had statoplasts, the horizontal ones none. It may of course be said that the result depends on the effect of shock lasting longer in some individual roots, since, as Czapek has well said, the only proof of the disappearance of shock effect is the act of curving. But since the operation was approximately the same in all the roots, it is hard to believe in such a malicious coincidence as that the shock was smaller in all those roots which produced statoplasts. But it may be said that shock prevented both geotropism and statoplast-formation in certain roots.

Czapek (02) quotes the experiment of Brunchorst, who found that a circular cut round the tip, not deep enough to free the terminal part, has the same effect as

[1] Němec (01). [2] F. Darwin (03).

[3] Czapek's results (02, p. 118) are in harmony with Rothert's experiments on the heliotropism of *Setaria*, &c. [4] Němec (04, pp. 46, 53).

[5] This agrees, as Němec says, with Wachtel's (99) result, who found geotropism returning before the whole tip was regenerated.

amputation. On the other hand, Němec[1] states that geotropism persists, if the root-tip is cut half through by two opposite incisions in different planes, so that the whole of the tissues are divided, and yet the tip is not amputated. Thus four out of five bean roots treated in this way showed distinct geotropism in $5\frac{1}{4}$ hours. This seems to me a striking result, as showing that the shock of the operation is not exclusively the decisive element. Němec has, moreover, shown that if geotropic curvature has begun on a normal root, a wound interferes with the amount of after-effect, and that the precise nature of the wound is not decisive, and this, as far as it goes, confirms the assumption that two half-cuts would produce as much shock as actual amputation.

Czapek[2] finds that splitting a bean-root longitudinally has the same effect as decapitation. This would mean that decapitation produces its results by shock only, since in a split root there is no removal of the tip. I think I was the first to make use of the splitting of roots in this connection. I wished to show[3] the incorrectness of Wiesner's view—viz., that amputation prevents geotropism by checking growth. In my experiments the split roots were greatly checked in growth, but curved geotropically, behaving in this respect quite differently from amputated specimens.

Another striking bit of evidence on Czapek's side of the question[4] is the fact that Lupin roots from which '$\frac{1}{2}$ mm. of the tip has been removed, and which, therefore, contain no statoliths,' show the remarkable homogentisin reaction which he has convincingly proved to be a symptom of graviperception. Czapek adds that the same is true of roots from which 1 mm. has been removed. It seems to me that Němec's reply to this[5] is of value. He finds that the root-cap in Lupin is variable in length, but always longer than $\frac{1}{2}$ mm.; therefore, in the roots from which $\frac{1}{2}$ mm. only was removed there should have been some statocyte tissue remaining. Even after the removal of 1 mm. the root can, according to Němec, rapidly form statocytes, since the section is in the neighbourhood of the calyptrogen.[6]

Němec suggests it to be conceivable that differences of pressure in Czapek's sense may give rise to the homogentisin reaction, while the true act of graviperception is confined to the statoplasts. This is no doubt possible, but I confess that, if the homogentisin reaction can occur in root-tips which have no statoliths I should consider it a strong argument in favour of the view that pressure-difference in Czapek's sense supplies the machinery of perception in roots. Czapek also claims that his experiments with bent-glass tubes (Czapek, 95) prove the graviperceptive region of the root not to be confined to the region of statoplasts, since if the root-cap alone is in the vertical branch of the tube, geotropic curvature is not excluded. Němec (04) has attempted a rejoinder to this objection; with what success readers must judge for themselves.

It will be seen that, in my opinion, the balance of evidence is not fatal to the statolith theory. Czapek, who treats the question in a broad and liberal spirit, is by no means inclined to deny that statoliths have a share in graviperception; all he claims to prove is that the statoplasts do not supply the whole of the mechanism. It is not easy for an upholder of the theory to allow this much in the present stage of the controversy. The best way of testing the theory is by comparing the distribution of geotropism with that of statoliths; and if we are to allow, in all cases which are opposed to the statolith theory, that the stimulus depends on pressure differences in Czapek's sense, we deprive ourselves of the best means of proving the truth or falsehood of our theory. Those who uphold the theory must have the courage of their opinions and finally trust to the facts of distribution. But further knowledge is necessary before such a judgment can fairly be made.

[1] Němec (01, p. 19).
[2] Czapek (98, p. 202), and (02, p. 118).
[3] F. Darwin (82).
[4] Czapek (02, p. 468).
[5] Němec (04, p. 53).
[6] He adds that the calyptrogen may in this way have an indirect importance, and Firtsch's belief that this tissue was the essential seat of graviperception may be accounted for.

Centrifugal Force.

Jost[1] objects that plants on a centrifugal machine do not behave as the theory would lead us to expect. Thus he found that certain roots and seedlings showed geotropic curvature, although the statoplasts were scattered through the cell, not spread out on the cell-walls furthest from the axis of rotation. Miss Pertz[2] and I have repeated some of Jost's experiments, and have come to an opposite conclusion. We find that *Setaria* does not curve with a centrifugal force of less than 0·02 g., and this is about the limit for visible displacement of the starch-grains. As the centrifugal force increases up to 0·04 we get slight amounts of curvature and slight amounts of starch displacement. The two phenomena cannot be accurately compared, but so much is clear: that the result of Knight's experiment is not destructive of the statolith theory, but, on the contrary, is roughly in harmony with it.

The result of an intermittent stimulus may seem to some a difficulty. Jost[3] produced geotropic curvature by placing seedlings in the horizontal and vertical positions for alternate periods of 3½ minutes. With alternate periods of 50″ horizontal and 2′ 30″ vertical he sometimes failed to get a geotropic curve, and exposures if less than 50″ always failed. It is commonly said that 15–25 minutes are needed for the starch to fall on to horizontal cell-walls, and it may seem, therefore, that in these experiments neither 3½ minutes (nor, *a fortiori*, 50″) could produce a change of position in the statoliths, and that therefore the experiment is destructive to the theory. But this would be a wrong conclusion, for, according to my experience, the falling time of starch is often less than 15 minutes; and even if this were not so there would be no difficulty in understanding the above experiments, for, as Jost allows (*loc. cit.*), and as Němec (02) has also pointed out, the statoplasts may stimulate the cell without the occurrence of any visible displacement; for if the statoplasts do not fall over and spread out on the horizontal walls there must be a column or heap of starch-grains, whose height equals the width of the cell, resting on the lateral wall of the cell instead of, as in the normal position, a shallower layer pressing on the basal wall. Here we have plain conditions of differentiation between the vertical and horizontal positions.

The same considerations apply to the whole question of what is known as the geotropic presentation time[4]—*i.e.*, the minimal period of horizontality needed to induce a geotropic curvature. It has been said that the presentation time corresponds with the time needed for the statoliths to fall on to the horizontal walls of the sensitive cells. It seems to me that we hardly have knowledge enough to be certain of this coincidence, and since, as above pointed out, the statoliths may begin to stimulate before they are visibly displaced, the question is not one of much interest or deserving of special inquiry.

Theoretical.

Elfving's[5] well-known experiment with grass haulms shows that (in this instance) the action of the klinostat depends, not on the prevention of all graviperception, but on the equal distribution of stimulus.[6] But other plants react differently—that is to say, they do not exhibit increased rectilinear growth on the

[1] Jost (02).

[2] Darwin and Pertz (04). By an oversight we omitted to give a reference to Němec's (02, p. 347) interesting reply to Jost's criticism.

[3] Jost (02), p. 175. See also Czapek (98), p. 206; and Noll (00), p. 462.

[4] Czapek (98), p. 183.

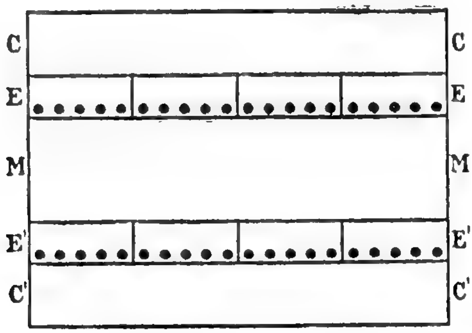
[5] Elfving (84) proved that the pulvini of grass haulms increase in length when kept in slow rotation on a klinostat.

[6] My experiments on the germination of Cucurbita demonstrate the same point (Darwin and Acton, 94). Czapek (02, p. 469) shows that the homogentisin reaction occurs on the klinostat.

klinostat. This can best be accounted for, as Noll[1] suggests, by the supposition that the equally distributed stimulus tends to produce a simultaneous increase and decrease of growth-rate on opposite sides of the rotating plant.[2] We, therefore, get in an indirect way evidence in favour of what has not been directly proved—namely, that in geotropic curvature the diminution of growth on the concave side is not the result of compression produced by increased growth on the convex side, but rather an independent reaction. It is necessary, therefore, to inquire what theoretical conclusions may be fairly made as to the stimulation correlated with such a mechanism of curvature. Noll[3] uses the term 'Reizfeld,' or 'stimulation-area,' to express the regions in which graviperception occurs. The distribution of these areas is expressed in diagrams which serve as shorthand methods of recording the geotropic reactions of various organs. All such ways of clarifying and expressing our ideas of the laws of perception are useful. I must confess that I do not find Noll's terminology easy to use, and I prefer to express the same ideas in terms of the distribution of the pressure of statoliths on the different parts of the ectoplasm of the gravisensitive cells.

Imagine an apogeotropic shoot placed in the horizontal position as shown in longitudinal radial section in fig. 2, where C and C′ are the cortical tissues and

FIG. 2.



the seat of motile power; E and E′ the endodermis, the supposed region of graviperception; M, the central tissues, which do not concern us.

The fact that the statoliths now rest on the horizontal (tangential) walls differentiates the horizontal from the vertical position of stable equilibrium. But what circumstance is there that can be conceived to originate curvature in one direction more than another? It can only be that in the endodermis E on the physically upper side the statoliths rest on the inner tangential wall, whereas in E′ they rest in the outer wall. This view agrees with Noll's hypothesis of the arrangement of stimulation-areas. There is no difficulty in believing that the inner and outer tangential walls have different individualities: Vöchting's work[4] on transplantation seems to indicate that this is the case. And if this analogy with formative polarity is not allowable, we must still insist that the presumption is in favour of E and E′ in fig. 2 being in different conditions, since we have certainly no right to assume that the outer and inner walls are identical in what we have called their individuality.

It is not here necessary to go into the question whether the radial walls of the endodermis are or are not sensitive, since the problem of geotropism in its broad outlines is not concerned with it.[5]

[1] Noll (92, p. 35).

[2] We have shown (Darwin and Pertz, 04) that in *Setaria* the statoliths undergo changes of position on the klinostat, indicating a succession of stimuli. See Heine (85), who briefly describes similar changes.

[3] Noll (92, p. 19).

[4] Vöchting (92, p. 151).

[5] See the discussion in Haberlandt (03, p. 467).

The Position of Maximum Stimulation.

This problem involves the question whether an orthotropic organ in the vertical position is or is not freed from stimulus. We will first take the question as to the existence of a stimulus in the normal (*i.e.*, not the inverted) position. One of Pfeffer's [1] arguments for the existence of a stimulus is as follows. A root having been allowed to curve from the horizontal to the vertical position is placed on a klinostat, and after a time the curve disappears. It is therefore assumed that there existed a geotropic stimulus keeping the root curved until the stimulus in question was rendered inoperative by the klinostat, when the rectipetality of the root could have free play. But it is not a necessary conclusion that while the root is strictly vertical any stimulus is acting. If from some internal cause the root leaves the vertical, the ordinary geotropic curvature depending on the stimulation of the tangential walls will come into action and bring the root back to the vertical. To translate into the language of the statolith theory, it is not necessary to assume that the lower walls of the graviperceptive cells are sensitive to the pressure of the statoliths—the sensitiveness of the tangential walls will suffice. The experiment above mentioned does not therefore seem to prove that an orthotropic organ in stable equilibrium is stimulated. But it is quite conceivable that a stimulus might be originated by the *loss* of pressure on the lower wall, for this would be a well-marked change in the internal condition of the cell, and therefore might become associated with a reflex. Thus, when an organ is placed horizontal the stimulus from the pressure of statoliths on the lateral walls (now horizontal) may be combined with, or in some way influenced by, the loss of pressure on the terminal wall of the cell which was formerly horizontal. But if the absence of pressure on a cell-wall acts in this way are we not bound to consider the pressure (when present) as a stimulus? I think we are, and therefore, though I do not think that the particular experiment referred to supplies the necessary evidence, I hold the lower wall of an orthotropic cell to be sensitive to the stimulus of statoliths, though such stimulus cannot be of a *directive* nature.

Since an organ when accurately inverted [2] and prevented from circumnutating receives no impulse to curve, it is assumed that the normally upper cell-wall (which is now below) is not stimulated. According to the statolith theory it is inconceivable that the organ should curve, since uniform pressure on the horizontal terminal wall cannot determine the *direction* in which such curve shall begin.

But though no directive stimulus seems to be a possible result of uniform pressure on the end-walls, it does not follow that such pressure has no effect. It seems to me that such a striking change as pressure on a wall which under normal circumstances does not receive pressure may very well modify the result of the normal stimulation of the lateral walls of the cell.

Czapek [3] has shown that with both stems and roots the gravistimulus is greater when the organ is removed from the normal vertical position by 135° than when it deviates from the normal by 45°. In the case of an apogeotropic shoot the position of the starch in the endoderm is given in fig. 3. The pressure of the starch on the lateral walls is the same in the two cases. In i., however, the starch rests partly on the basal wall (B), while in ii. it rests, to the same degree, on the apical wall (A). On the usual assumption that the basal and apical walls are insensitive, there is nothing to differentiate i. from ii. I cannot help suspecting that the pressure on the apical wall does in some way affect the sensitiveness of the tangential walls. If the pressure on the wall (A) was in itself the decisive

[1] Pfeffer (93, p. 19). I am only concerned with this special point, not with Pfeffer's general argument.

[2] In the whole of this discussion the organs are supposed to be supported by the morphological base.

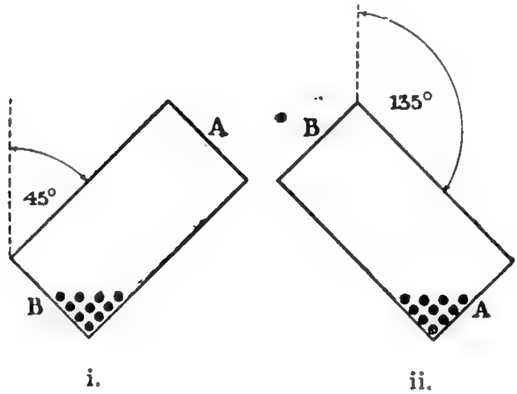
[3] Czapek (95, 1). As doubt has been expressed as to the actual facts, it is worth while mentioning that Miss Pertz (99) has confirmed his results for the haulms of grasses.

element we should expect the stimulus to increase as the angle increased—from 135° to nearly 180°—which is not the case. From my point of view we can dimly understand why 135° should be the position of maximum stimulation. It would be the result of a compromise, being a position in which the combined pressure on both lateral and apical walls was as high as possible[1]—a mean, in fact, between full pressure on the lateral walls (as in the horizontal position) and full pressure on the apical walls (as in the vertical position).

If some such theory is not adopted we must imagine with Haberlandt that the difference between positions i. and ii. depends on the weight of the statoliths in i. being on the *basal half* of the lateral wall, and on the apical half in ii. It seems to me that the difference of sensitiveness in the two regions would have to be very great, considering that in the horizontal position, in which the gravistimulus is less than in position ii., the full pressure of a considerable fraction of the total starch acts on the supposed extra-sensitive region of the cell-wall.

But when all has been said there remains a difficulty with which I do not

FIG. 3.



know how to deal. It is clear that, according to either theory, the critical position should be the horizontal, and that as the organ is moved further and further from the normal (in successive experiments) the geotropic reaction ought to increase decidedly as the horizontal is passed, and this is not the case.

Diageotropism.

The diagram, fig. 2, will serve to represent a diageotropic organ in stable equilibrium. In spite of the fact that it is at rest in the horizontal position, we must assume that the tangential (horizontal) walls of the endodermis are sensitive to the pressure of the statoplasts. For when the organ is placed obliquely it has the power of returning, by curvature, to the horizontal; and this requires that the plant shall distinguish up from down. If its apex is above the horizon it must curve downwards, *i.e.*, towards that side on which the statoplasts rest on the *external* walls of the endoderm cells, and *vice versa* if the apex is below the horizon. But what signal tells the plant that it is not horizontal? This can only be effected by the statoplasts pressing on the basal or apical walls, as in fig. 3.

The difficulty is increased by the fact that when a diageotropic organ is fixed vertically, the apex being up or down,[2] no curvature follows. This, according to

[1] The fact that at angles above 135° the stimulus remains greater than when the organ is horizontal seems to point to the conclusion that the share of the end wall in graviperception is relatively great.

[2] Czapek (98, p. 243). Noll (92, p. 37), had foreseen on theoretical grounds that this would prove to be the case. See also Noll (00, p. 473).

the usual idea, would mean that the terminal walls are not sensitive. But the walls must be sensitive in some way, or the plant would not react to the gravi-stimulus, as it undoubtedly does. The only conclusion I can come to is that the position of the statoliths shown in fig. 3, in which they rest partly on the terminal wall and partly on the lateral (tangential) wall, must be capable of giving the combined stimulus,[1] as above suggested.

Personally I do not attach great importance to the details of how the statoliths act on the different walls of the cells, although as part of the history of the inquiry I feel bound to discuss it. The broad fact that the statoliths rest on different parts of the cell-walls when the geotropic organ is placed at different angles with the vertical seems to me sufficient. The precise manner in which various reactions are associated with the position of the statoliths may be confessed to be for the present beyond our knowledge or powers of imagination, and such confession need not weaken the position of our theory.

Finally, I desire to say a word on a subject having but a remote connection with my theme. There is at the present time a tendency to pay an increasing attention to what is known as rectipetality or autotropism—viz., the inherent capacity of rectilinear growth. In my Cardiff Address[2] to Section D I showed that rectipetality is really part of the phenomena of circumnutation. We must believe that rectipetality does not merely come into play in those comparatively crude experimental instances in which a geotropic curvature is flattened out by means of growth on the klinostat. We must believe that it also corrects curvatures which arise from the slight irregularity of normal every-day growth. This will imply that normal growth is built of a series of internal corrections; in other words, of circumnutation. The point I wish now to emphasise is that the stimuli, be they of geotropic or any other nature, should be conceived as acting not on a stationary but on a moving plant—acting, in fact, on the spontaneous correcting power, whether we call it rectipetality, autotropism, or circumnutation. It is impossible to say how this consideration might modify our speculations as to the manner of action of the gravistimulus. It is quite conceivable that it might not alter our theoretic views at all, but without more knowledge we cannot be certain. My only point at present is that if we are led into contradictions or confusion by attempts to analyse what goes on in the gravisensitive region according to the statolith theory, such a result must not be held to be fatal to the theory until we know more of the problem.

In conclusion—and to clear our minds of the doubtful speculations in which I have entangled myself—I should like to reiterate my belief in the general, though not the universal, applicability of the statolith theory. I find it impossible to doubt that, in the case of the higher plants, sensitiveness to the pressure of heavy bodies will be found to be by far the most important, if not the exclusive, means by which gravity is perceived. We have seen that the stimulus must depend on weight; and since neither the theory of radial pressure nor Noll's supposition of stimulation by small unknown bodies lends itself to experimental inquiry we are driven, as practical people, to test the views of Haberlandt and Němec.

I base my belief partly on what I have already said, namely, that geotropism, being an adaptive reflex action, must during its development have been correlated, by that mysterious bond which unites stimulus to reaction, with some change, by which in the natural course of events it is uniformly preceded. Now the most obvious change which precedes geotropism is the disturbance of the falling starch-grains. This fact, together with what we know of the distribution of statoplasts, would almost force conviction on me. But this is not the whole of the evidence. We know from Němec's researches that the protoplasm, in the cells assumed

[1] In Noll's diagram of the stimulation-areas in a diageotropic organ the obliquely placed areas seem to suggest a similarity to what is here given [see Noll (92, p. 29)]. But his stimulation areas in which only a single statolith occurs are not strictly comparable to cells containing numerous statoplasts.

[2] F. Darwin (91).

to be sense-organs, is sensitive to the pressure of the statoplasts; and we know from zoological evidence that heavy bodies resting on a sensitive surface can function as a sense-organ for gravitation. Finally, the experimental evidence, though not absolutely convincing, has not revealed any absolute bar to our belief in the statolith theory, and has brought to light a number of facts harmonising with it in a remarkable manner. It seems to me that the theory of Němec and Haberlandt may fairly hold the field until a better theory of graviperception and a better theory of the function of falling starch-grains are established.

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The following Papers and Reports were read:—

1. *A New Type of Sphenophyllaceous Cone from the Lower Coal Measures. By* D. H. Scott, *M.A., Ph.D., F.R.S.*

This strobilus was found by Mr. J. Lomax, jun., in petrified material from Shore Littleborough, in Lancashire, a locality rich in fossil remains, which has only recently been opened up through the energy of Mr. Sutcliffe.

The specimen, which is incomplete, is about $2\frac{1}{2}$ inches in length by half an inch in diameter. The preservation is good, and a number of excellent sections have been obtained.

The axis of the cone is traversed by a triarch stele, exactly agreeing in structure with that of a young stem of *Sphenophyllum.* The close relation to that genus is confirmed by the division of the appendages into dorsal and ventral lobes.

The cone differs, however, from all known Sphenophyllaceous fructifications

in the fact that, so far as could be ascertained, all its appendages were fertile. No indication of sterile bracts is met with.

The appendages are only slightly connate at the base; each lobe, whether dorsal or ventral, divides palmately into several segments, the sporangiophores. The sporangiophore consists of a slender pedicel terminating in a peltate lamina of somewhat complex structure, bearing two pendulous sporangia. In this respect the new cone resembles the *Bowmanites Römeri* of Solms-Laubach. The structure of the sporangial wall agrees, on the whole, with that met with in other Sphenophyllaceous and Calamarian strobili. The spores, so far as observed, are all of one kind, and are of ellipsoidal form, with longitudinal ridges on the outer membrane.

The fructification may provisionally bear the name *Sphenophyllum fertile.*

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2. *On some New Lagenostomas. By* D. H. Scott, *M.A., Ph.D., F.R.S., and* E. A. Newell Arber, *M.A.*

The recent discovery, based upon evidence from petrified material, that *Lagenostoma Lomaxi,* Will. in MS., is the seed of *Lyginodendron,* a genus of Cycadofilices now placed in Pteridospermeæ, has been followed by the recognition of more than one new species of *Lagenostoma* preserved in the condition of casts or impressions. The specimens in question have also thrown light on the manner in which the seeds were borne. The new species differ in their external morphology from all those previously described. In one of them, which we propose to name *L. Kidstoni,* the seeds are naked, but in the other, *L. Sinclari,* Kidston in MS., there are indications of an external envelope or cupule. In *L. Kidstoni* the seed is lobed at the free end, recalling the structure of the petrified seed *L. physoides,* Will.

Both the new seeds are found in close association with rachis-like structures; in the case of *L. Sinclari* continuity is obvious, for the seeds are borne terminally on branches of the slender rachis.

In *L. Kidstoni* the evidence of connection is less decisive, but in one case the seeds appear to be *in situ* on one of the finer branches of the rachis. Thus in both cases the seeds were apparently borne on the ultimate branches of a frond in which the lamina had been greatly reduced. There are indications that the fronds were of the *Sphenopteris* type.

Both species are derived from the Lower Coal Measures of Scotland. The authors are much indebted to Mr. R. Kidston, F.R.S., for his kindness in lending them the specimens of *Lagenostoma Sinclari* for investigation.

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3. *Observations on Structure of the Leaf-trace of Inversicatenate Filicinæ. By* Professor C. Eg. Bertrand *and* Professor F. Cornaille.

In the living ferns the conducting element is a bipolar bundle (F). The bundles arrange themselves into single chains joining one another by their poles. When there is a breach of continuity, it occurs in the centre of figure. If there is one breach involving two consecutive bundles of the chain, it isolates a *divergeant,* which can also serve as distinct element, which we letter Y.

Again, all leaf-traces of living ferns present a posterior arc, whose concavity is turned towards the upper part of the frond; they have also two anterior half-arcs, which are turned in from the marginal face towards the anterior face and toward the plan of symmetry of the frond; they can be also joining others at the concavity of the posterior arc. The variations observed, such as the *quadruple element* of *Asplenium nidus, Scolopendrium officinale, Marsilia,* are modifications which can bear an obvious relation to the general arrangement of a chain, as the one of *Osmunda regalis.*

The object of the study of Professors Bertrand and Cornaille is to show that

the leaf-trace of Filicinæ is built on the same plan as that of Anachoropteris, Botryopteris, Zygopteris—that it had the same elementary pieces, which unite in the same way. This study indicates the special characters of the three types of traces and the inversion of the curvature of the chain in the leaves.

Anachoropteris shows in the leaf-trace bipolar bundles united pole to pole, and breaches in the centre of figure. The inverse curvature of the chain in Anachoropteris was indicated by Corda. It is confirmed by sections taken in the ramifications of the petiole, and by the study of specimens in which the fronds still surround the *stipe* which bears them. The study of the last specimens was made by M. Stenzel.

The leaf-trace in Anachoropteris is a binary chain, the curvature of which is inverted. It has, consequently, two anterior double poles and wings which turn backward. When these wings are long they are prolonged into spirals, but they do not meet and the chain remains open.

The emission of lateral pieces (veins or petiolar traces) is always effected by the separation of *closed inverse divergeant 'à œil ouvert'*—that is to say, with an ingrowth of phloem into the centre; or *'à œil plein,'* where no such ingrowth occurs.

This mode of emission is comparable with that one of *Asplenium nidus*, and with that of *Microlepia*. The lateral piece takes only a little part of the half anterior arc. The lateral emissions come off between the interior face of the half-anterior arc and the anterior face of the leaves.

In the upper ramifications of the frond the leaf-trace is reduced to a closed inverse *divergeant* retaining the character of its curvature even when much reduced.

In the leaf-trace of the Botryopteris type the chain of the petiole may be divided into (1) a trunk, (2) a *receptive chain* on either side, which receives (3) the branch chains (or veins).

The characters of traces of the Botryopteris type are a binary chain of inverse curvature, the posterior arc of which is much reduced and may disappear. The anterior half-arcs are large; they may join posteriorly, and so close the chain. The anterior bundle, F^{Ma}, touches on a large area the bundle of the posterior arc, F^{Ms}.

The branches always come off from the beginning of the anterior half-arcs. The largest phloem elements (sieve tubes) occur on the flanks of the anterior bundle and in front of the posterior bundle. The surrounding phloem morphologically is an internal phloem. The morphological external phloem is crowded out. All the branches given off on the same side are reduced to a closed inverse *divergeant 'à œil plein,'* and unite to form a *receptive chain* whose poles are external. The two receptive chains of right and left unite together in front of the point where the trunk chain is closed.

Here is a remarkable development of the anterior face, which begins to extend round the far side. The trace retains the same characters even in the superior ramifications, and this is found in the whole series, from *Botryopteris forensis* to *Rachiopteris tridentata.*

The characters of the Zygopteris trace, taken in its most differentiated type, say, *Zygopteris Lacattii*, are a quatenary unopened chain of inverse curvature, whose margins (points of ramification) are occupied by a complete bundle. The anterior bundle, F^{Ma}, touches widely the posterior bundle, F^{Ms}, which is nearer to the anterior face. The emissions occur in four symmetrical spots. There are four large *receptive lobes*, constricted at the base, where they join a *median apolar piece.*

The emission is effected by a closed inverse *divergeant 'à œil plein.'* The two emissions of the same side may unite, at least for a short distance, into a single chain of apparently direct curvature. Two or four lines of lateral ramification are possible. They are always formed of closed inverse *divergeants* associated into a chain of direct curvature. The receptive lobes disappear in the forms *Zygopteris duplex*, *Dineuron pteroïdes.* They become receptive prolongations in *Diplolabis esnostensis*, and in the species from *Zygopteris insignis* to *Zygopteris*

bibractensis, where the last chain at its emission unites the two polar marginal points. These remarkable peculiarities correspond at the emissions with an *unopened marge.*

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4. *On the Presence of Parichnos in Recent Plants.* *By* T. G. Hill.

If a mature sporophyll of *Isoetes Hystrix* be examined, there will be seen in the lateral expansions of its base two longitudinal cavities containing a certain amount of mucilage, and situated one on each side of the vascular bundle in close proximity to the sporogenous mass.

By the examination of sporophylls in different stages of development, it may be ascertained that the above-mentioned canals arise by the mucilaginous degeneration of two strands of parenchyma.

The structure in question does not extend into the cortex of the stem, but is confined entirely to the base of the sporophyll, its limits seemingly depending upon the extent of the sporangium.

Whether the same features obtain in sterile leaves has not been determined, owing to the lack of material. Indications of a similar structure were observed in other species of *Isoetes.*

It is suggested that these strands of degenerating tissue, and the resulting mucilage-containing canals of the mature leaf, represent the parichnos occurring in *Lepidodendron*, *Sigillaria*, *Lepidocarpon*, &c.

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5. *The Anatomy of* Psilotum triquetrum. *By* Miss Sibille O. Ford.

Psilotum triquetrum consists of a much-branched aerial stem and rhizome. The leaves are much reduced and have no vascular supply. There are no roots.

The plant is monostelic throughout. At the base of the aerial stem a protostele is found, and this, higher up, may be succeeded by a medullated stage with no inner phloem or endodermis. Secondary tracheids may occur (Boodle). In the aerial branches a central core of sclerenchymatous fibres is found, surrounded by xylem with radiating groups of protoxylem. In the rhizome the xylem forms an irregular mass with no fibres, and the protoxylem consists of ordinary scalariform tracheids.

The phloem throughout is feebly developed, and lignification of this tissue may occur in the aerial stem.

A three-sided apical cell is present both in the aerial stem and in the rhizome.

From the nature of the sporangial apparatus the *Psilotaceæ* have been regarded as possessing a close affinity with the fossil *Sphenophyllales.* There is also a strong resemblance, anatomically, to some of the fossil Lycopods, especially to the stem of *Lepidodendron mundum*, as well as to the axis of the cone of *Lepidostrobus Brownii.*

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6. *Seed-coats of Cycads.* *By* Marie C. Stopes, *Ph.D.*, *B.Sc.*

A number of species in various stages of the ovules of *Cycas*, *Zamia*, *Macrozamia*, *Ceratozamia*, *Encephalartos*, *Bowenia*, and *Dioon* were examined.

The usual description of the integument as a single one, differentiated into two layers, an outer fleshy and an inner stony, is found not to hold good. In all the above-mentioned genera there is also a soft inner integumentary layer, which is sometimes greater in diameter than the outer fleshy layer; frequently it and the nucellus are crushed together by the growing prothallium, but this is by no means always the case; sometimes it remains fresh quite late.

Two series of vascular bundles run in the ovule, and it is proved that the inner series, frequently described as 'nucellar,' belongs to the soft inner layer of the integument. These bundles do not invariably die out at the region where the nucellus becomes free from the integument, as hitherto supposed, but in more than

one species are found continuing in the inner layer of the integument almost to the micropyle.

The bundles running in the outer flesh are mesarch, centripetal xylem sometimes being developed in great quantity. The presence of this primitive type of bundle in the ovules is in itself of interest, as is the comparison of these bundles with the mesarch ones in the free fleshy 'cupule' of Lagenostoma.

The view is brought forward, chiefly on anatomical grounds, that the inner fleshy layer with its system of bundles represents an inner integument. The stone layer is considered as a differentiation of the outer flesh, and with its distinct system of bundles forms the second or outer integument. The two are completely grown together, as is the case in some genera of Rosaceæ, &c.

On the basis of the arrangement of the bundles in the ovule and the supply bundles of the sporophyll the genera may be placed in a series, of which *Cycas* is not the 'most primitive,' but the least primitive of the group. All the genera have approximately radial symmetry but *Cycas*, which is bilateral and shows distinct traces of an original radial symmetry.

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7. *A New Feature in the Morphology of the Fern-like Fossil* Glossopteris. *By* E. A. Newell Arber, *M.A.*

This preliminary note records the discovery of small, almost microscopic sac-like bodies in association with the 'scale-fronds' of *Glossopteris*; a fern-like fossil abundant in the Permo-Carboniferous rocks of India and the Southern Hemisphere. These bodies are oval in form, measuring about 1 mm. along the greater diameter, and are prolonged at one extremity into a short and often bent neck; thus resembling a retort in shape. The anatomical structure is not preserved, but the preservation, as impressions, is very perfect. The sacs are marked by pseudo-parallel striæ in the direction of their greater axis, and these striæ anastomose at intervals. The striæ are no doubt the impressions of the cell-walls of the sac.

The material showing these bodies is at present too scanty to permit of any definite conclusion as to their nature, whether sporangial or otherwise.

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8. *On Reduction of the Gametophyte in* Todea. *By* L. A. Boodle.

It has often been observed that, among the homosporous ferns, germination of spores under crowded and unfavourable conditions leads to the production of small prothalli bearing antheridia only.

An extreme case of the formation of dwarf male prothalli occurs in *Todea Fraseri* under certain cultural conditions. The dehiscence of the sporangia may be delayed, sometimes permanently, and many of the spores then germinate within the sporangia. The early stages of germination may be normal, or more often an antheridium is produced almost at once. In the latter case the prothallus proper may consist of only two or three cells contained in the burst exosporium, from which the antheridium with its basal portion projects. Frequently no rhizoid is present.

If ripe sporangia be artificially ruptured and the spores sown on a damp substratum or in water, germination is normal and the prothallus attains a considerable size without production of antheridia. Dwarf prothalli bearing antheridia, when released from the sporangia and sown, were not found to undergo any further growth.

A comparison of the present case with that of the microspores of *Salvinia* has a special interest, as illustrating how a reduction of the prothallus, approaching that shown by the latter plant, may be brought about by the non-dehiscence of the sporangium in a species of fern specialised to a very damp habitat, *excessive* dampness of the atmosphere being very possibly the direct cause of the suppression of dehiscence.

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9. *On the Reduction of the Marchantiaceous Type in* Cyathodium. *By* William H. Lang, *M.B., D.Sc.*

The species of *Cyathodium* grow in damp, shaded situations in the tropics, and exhibit a simplification of structure as compared with other Marchantiaceæ. A detailed examination of *C. fœtidissimum,* a larger, less reduced form, and *C. aureo-nitens* (which agrees closely with *C. cavernarum,* investigated by Leitgeb) confirms the systematic position close to *Targionia* usually assigned to the genus.

As compared with *Targionia* the species of *Cyathodium* appear to constitute a reduction series, the reduction affecting both the gametophyte and the sporogonium. The thallus, as is well known, is greatly reduced in thickness; the layer of air-chambers opening by simple pores is retained, but assimilating filaments are absent from the chambers. Assimilation is mainly performed by the cells of the epidermis, which are adapted to utilise the feeble light in the same way as the lens-shaped cells of the protonema of *Schistostega.* The lower tissue of the thallus is for the most part composed of a single layer of cells. *C. fœtidissimum* has, however, a narrow midrib several cells thick, the cells being inhabited by an endophytic fungus. The amphigastria are reduced to small scales composed of thin-walled cells in *C. fœtidissimum,* and to simple rows of cells in the other two species. Both smooth and peg rhizoids occur in *C. fœtidissimum,* but in *C. aureo-nitens* all the rhizoids are thin-walled. Branching of the thallus in both species occurs dichotomously and by the formation of adventitious branches from the lower surface just within the margin.

The archegonia in *C. fœtidissimum* are produced from the apex of a branch which becomes displaced towards the ventral surface. They thus occupy the same position as those of *Targionia,* and, as in that genus, the displaced margin grows up as the involucre, which becomes completed behind by the further growth of the apex itself. In *C. aureo-nitens* the archegonia are found in acropetal succession on the upper surface of the apical region of a branch of the thallus. The apex, after forming the archegonia, grows on to form the involucre, which is roofed in by the limiting layer of the last formed and incomplete air-chamber. The development and structure of the archegonium is as in *Targionia.*

The antheridia are borne on short disc-shaped adventitious branches. In *C. fœtidissimum* an antheridial branch is situated in the middle line below, just behind the archegonial group or groups. In *C. aureo-nitens* the branches are borne close to the margin, and usually alternate with the archegonial groups. The antheridia completely fill the cavities in which they are sunk singly; each antheridium consists of a stalk two or three cells in length, a wall of a single layer of large clear cells, and the central group of spermatocytes.

The first divisions of the fertilised ovum in *C. fœtidissimum* agree with those in *Targionia,* but in *C. aureo-nitens* a row of four cells is formed before longitudinal divisions appear. The mature sporogonium consists of a capsule the wall of which is one layer of cells thick, except at the apex, where a definite group of thin-walled cells is present, and a short cylindrical foot. The foot in *C. fœtidissimum* is composed of four rows of cells, in *C. aureo-nitens* of a single row except at the base, where a group of four cells is present. These basal cells, which are throughout recognisable by their larger size, grow out in both species into short branched processes, which ramify among the surrounding cells; this occurs about the time of the division of the spore-mother-cells. Thickening bands are present on the cell-walls in the upper third only of the capsule wall in both species. The cells of the lower part of the wall in *C. fœtidissimum* have their internal walls brown, but present no special peculiarity. Those of this region in *C. aureo-nitens* are thin-walled, packed with starch, and have nuclei which are enlarged and of abnormal appearance.

The sporogonium of *C. fœtidissimum* is much smaller than that of *Targionia*; the spores are smaller than those of the latter, but, like them, are thick-walled. The sporogonium of *C. aureo-nitens* is only about half the length and breadth of that of *C. fœtidissimum,* but the spores are few in number and absolutely

as well as relatively larger than in the latter species. Well-developed elaters are present in both capsules.

It appears probable that *Cyathodium* has been derived by adaptation to damp and ill-lighted situations from a well-characterised Marchantiaceous form of about the same grade of differentiation as *Targionia*. The modifications of vegetative structure can readily be placed in relation to the change of habitat, while those of the sporogonium may have been indirectly necessitated by the reduction in bulk of the lower storage region of the thallus and especially of the portion bearing the archegonia.

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10. *On some* Peperomia *Seedlings.* *By* A. W. Hill, *M.A.*

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11. *Exhibition of Specimens illustrating* (1) *the Comparative Constancy of Specific Characters of Eucalypts* ; (2) *the Relation between the Leaf Venation and the Oil Constituents.* *By* R. T. Baker, *F.L.S.*

These exhibits consisted of a large number of herbarium specimens of eucalypts obtained from trees growing in different parts of the world, and demonstrate clearly that the varying environments have produced little or no variation of systematic characters, such as buds, leaves, fruits, and flowers. There was also exhibited a number of photographs, taken from living leaves, which show leaf venation of the various groups of eucalypts, the disposition of which indicates an agreement with the oil constituents, which latter were also exhibited.

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12. *Exhibition of Fruits of* Melocanna, Melocalamus, *and* Ochlandra. *By* Dr. Otto Stapf.

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13. *Observations on Secondary Thickening in* Amarantus spinosus. *By* Horace A. Wager, *A.R.C.S.*

This species of Amarantus is very common in Natal, being a troublesome weed and growing rapidly on any waste ground. It seems to be able to stand the variations of climate better than a large number of plants; and plants in Natal have to accustom themselves to extremely irregular conditions of heat and moisture during the growing season.

In its mode of secondary thickening it corresponds generally to the type described by De Bary ('Comp. Anat.,' &c., p. 590). The centre of the young stem is occupied by a number of scattered bundles in a succulent ground tissue. On the outside of these bundles is the meristem ring, from which new bundles are formed on the inside. In the older part of the stem the intermediate cells given off from the meristem ring become thickened and form a fibrous mechanical tissue, which becomes more strongly pronounced near the base of the plant. In the thickest stems of 5 centimètres diameter this strengthening ring is never more than 5 to 8 millimètres thick, but the stem is very strong and sturdy. The leaf trace bundles pass into the stem and immediately anastomose with those already in the centre of the stem, and only run for a short distance alone. A transverse section through a node shows a good deal of confusion, due to the anastomosing of the stem-bundles among themselves and also with the leaf and axillary traces.

In the lower part of the stem the bundles are more numerous in the mechanical ring, and do not increase in size so much as those in the central tissue.

The elements of the xylem are of the usual kind. The phloem is well marked, and contains fairly long sieve tubes with slightly oblique sieve plates. In most cases well-developed callus can be quite easily made out. This development of callus is surprisingly large in a plant which is an annual and only lives for a few

months. In the mechanical ring the phloem in many cases becomes separated from its accompanying xylem to such an extent that the phloem appears like phloem-islands.

The youngest roots exhibit a diarch structure with protoxylem in the centre. On the face of each group of xylem elements is a layer of cambium, and outside this a strand of phloem. In the older part of the root this becomes split up into four or more distinct bundles. At a considerable distance from these central strands of vascular tissue a meristem ring appears, and bundles are formed by it, as in the stem, but more regularly.

The origin of the secondary roots appears to be in the region of the protoxylem of the central strands, and they are always strongly connected from the first with it. Where secondary roots appear after the formation of the meristem ring, they are in all cases connected with the central strands and break through the meristem ring in their passage to the exterior.

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14. *Report on the Respiration of Plants.*—See Reports, p. 344.

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15. *Report on Botanical Photographs.*—See Reports, p. 345

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16. *Report on Experimental Studies in the Physiology of Heredity.* See Reports, p. 346.

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17. *Report on a Monograph of the Genus* Potamogeton.

Sub-Section of Agriculture.

Chairman—W. Somerville, M.A., D.Sc., D.Œc.

The Chairman delivered the following Address:—

The audience that I have to-day the honour of addressing may be assumed to consist of a considerable proportion of the members of the British Association, and some others, who are primarily interested in, and have themselves made appreciable contributions to, the progress of Agricultural Science. I may, therefore, take the opportunity of congratulating you on this fresh evidence of progress in the subject that you have at heart, and of offering to the British Association our thanks for the encouragement and stimulus which are associated with the formation of an Agricultural Sub-Section. Perhaps I rightly interpret your feelings when I say that for the present we are satisfied with the position attained by our subject, but that we trust to see this and other meetings demonstrating that Agricultural Science is not unworthy of further advancement.

In view of the large amount of work that lies before us during the next few days, I do not propose to intervene for long between you and the contributions to original research which we have been promised. The scope of my remarks will be limited no less by time than by the fact that it would be presumptuous in me to attempt to traverse the whole field of Agricultural Science, including, as it may be held to do, the no small compartments of Horticulture and Forestry. What I propose to do, therefore, is to confine myself to touching upon a few of the subjects that have recently been receiving attention at the hands of scientific investigators, especially abroad. I have purposely avoided discussing English work, partly because it may be assumed that we are all familiar with it, and partly because, where friends are concerned, selection is difficult.

Although Agriculture has only now been elevated to a position of semi-

independence in the programme of this Association, it has, in the aggregate, received much attention at the meetings inaugurated with that at York in 1831. It is interesting to turn up the early volumes of the Reports, and to ascertain what was running in the minds of our predecessors, and what the problems that they thought it vital to solve. In the account of the first meeting in this town in 1833 we find a Report by Lindley on the Philosophy of Botany, two of the items in which are of interest to students of Rural Economy. Apparently at that time much attention was being given to the mode of the formation of wood. Two theories appear to have divided botanists—the one that wood was organised in the leaves, and sent down the stem in the form of embryonic but organised fibres, to be deposited on the surface of wood already formed. The other theory was that wood was secreted *in situ* by the bark and older wood. It is to the former of these theories that Lindley gives his adherence. Although this problem has ceased to interest, the same cannot be said of another subject discussed in the same Report, namely, the so-called 'fæcal excretions' of plants. In the words of Lindley, 'A new apple orchard cannot be made to succeed on the site of an old apple orchard unless some years intervene between the destruction of the one and the planting of the other; in gardens no amount of manure will enable one kind of fruit-tree to flourish on a spot from which another tree of the same species has been recently removed, and all farmers practically evince, by the rotation of their crops, their experience of the existence of the law.' He attributes to Macaire the demonstration of the fact that all plants part with a fæcal matter by their roots. These excretions he held to be poisonous, maintaining that, although plants generate poisonous secretions, they cannot absorb them by their roots without death, concluding that 'the necessity of the rotation of crops is more dependent upon the soil being poisoned than upon its being exhausted.' He indicated the lines along which investigation might with advantage proceed, one of the questions put forward being 'the degree in which such excretions are poisonous to the plants that yield them, or to others.'

In 1833 botanists and agriculturists had not the advantage of the knowledge that is at our disposal through the continuous growth for a long series of years of certain crops at Rothamsted, but consideration of the fact that some crops (as, for example, pure forests of beech, silver fir, Scots pine and other trees, as also permanent pasture) may be grown for hundreds of years on the same ground without any evidence of poisoning, might have led to the conclusion that the law, as it was called, was not of general application. It is, of course, true that rotations are an advantage, and it is a matter of experience that certain crops—*e.g.*, clover and turnips—cannot be grown continuously on the same land, but the cause is not now associated with excretions. The reason for the failure of clover, or the cause of land becoming 'clover-sick,' as it is called, is still a debated point; but I may hazard the conjecture that it is due to the fact that organisms or enzymes inimical to the vital activity of the minute living bodies, that exist in symbiotic relationship with the clover plants, increase with great rapidity when the living bodies that they affect are present in abundance. Red clover is the species that is usually associated with the term clover-sickness, but it would appear that a precisely similar phenomenon is exhibited in the growth even of wild white clover. It is a matter of common observation that on certain classes of land white clover is stimulated to such vigorous growth by the use of phosphatic manures that for one year at least it monopolises the area to the almost total exclusion of other plants. But such rank luxuriance is not of long duration. In a year or two the clover disappears to a very large extent, and cannot at once be restored by any process with which we are acquainted. The land has, in fact, become sick to white clover. But given a period of rest, during which the inimical agents will disappear, and it again becomes possible to stimulate white clover to vigorous growth. We have, it seems to me, an analogous state of things in the case of certain insects. On the Continent the caterpillar of the Nun Moth (*Liparis monacha*, L.) periodically proves extremely destructive to certain conifers, and it is found that in the first year the insects are moderately abundant, in the second they are excessively abundant, while in the third the visitation begins to

decline, and usually terminates quite suddenly. The causes of this cessation have been thoroughly worked out, and are found in the great increase of parasitic insects, and insecticidal fungi, including bacteria. I believe it will be found that the almost sudden cessation of our periodic visitations of the diamond-back moth is due to a similar cause.

The failure of turnips is apparently largely, if not entirely, due to the increase of insects and parasitic fungi.

The subject of harmful excretions has recently obtained renewed attention through the work being done at the Woburn Fruit Station. No point has received more striking demonstration there than the harmful influence that growing grass exerts on fruit-trees. It has been shown that this prejudicial influence is not due to the withdrawal of moisture, to the curtailment of supplies of plant food, to interference with aeration, or to modifications of temperature. In Mr. Pickering's opinion,[1] 'the exclusion of all these possible explanations drives us to believe that the cause of the action of grass is due to some directly poisonous action which it exerts on the trees, possibly through the intervention of bacteria, or possibly taking place more directly.' It is satisfactory to know that the subject, which is of considerable scientific and practical importance, is likely to be vigorously followed up.

In the early forties attention was being directed to a subject that even now has a great attraction for agriculturists, namely, the stimulating and exhausting effect of artificial manures, especially nitrate of soda. The principle that 'stimuli lose their full effect upon living matter when frequently repeated' was generally held to account for the want of response that crops exhibited to repeated dressings of nitrate of soda; but Professor Daubeny in 1841[2] pointed out what is now generally accepted as the true cause, namely, the exhaustion of the soil of other substances. This, he said, can be counteracted by giving other manures, of which he instanced bone meal. His suggestions for future investigations have been largely followed, though, as we now know, they are of theoretical rather than practical importance. He proposed the alternatives:

1. Analysis of the soil, discovery of the amount of available plant food, and the application of the substances found to be deficient up to the probable measure of the crop's requirements.

2. Discovery, by analysis of the yield, or estimation by calculation, of the amount of plant food removed in the produce, and the application to the soil in the form of manure of what was withdrawn by the crop.

Daubeny suggested that manuring should be undertaken on a system of book-keeping—on the one side being entered all the items of plant food taken out by crops, and on the other all that is applied in the form of manures, the two sides of the account being made to balance. This theory of manuring is distinctly suggestive, and often fits in rather remarkably with actual practice, though the comparative agreement between theory and practice is due to causes that the author of the theory probably hardly contemplated. Take, for instance, the case of wheat. An average crop removes from an acre about 50 lbs. nitrogen, 30 lbs. potash, and 20 lbs. phosphoric acid. This loss would be restored by the use of some 3 cwt. nitrate of soda, 2 cwt. kainit, and $1\frac{1}{2}$ cwt. superphosphate; and on many soils wheat could, no doubt, be grown continuously for many years on such a mixture, aided by good tillage, without the yield suffering materially. But we now know that much of the plant food offered in manure never enters the crop at all, so that the balancing of the account is due almost as much to chance as to calculation. This becomes more apparent when we regard such a crop as meadow hay, which in actual practice is often grown for a long series of years on the same land. To balance the withdrawal of phosphoric acid by an average yield of this crop only about $\frac{3}{4}$ cwt. of superphosphate per acre is theoretically necessary, but on most soils an average yield would not be maintained by the use of so small a quantity.

[1] *The Effects of Grass on Apple Trees.* Journal R.A.S.E. Vol. lxiv. p. 365.

[2] *On Manures considered as Stimuli to Vegetation.*

During the fifties the volumes of the Association contain several important contributions from the two distinguished Englishmen to whom the world's agriculture owes so much, Lawes and Gilbert. Their first contribution was made in 1851, and dealt with Liebig's mineral theory, a subject with which their names will always be associated. They drew upon their rich store of experimental data to prove that the yield of wheat is much more influenced by ammonia than by minerals, and they gave it as their deliberate opinion that the analysis of the crop is no direct guide whatever as to the nature of the manure required to be provided in the ordinary course of agriculture. With the reservation 'in the ordinary course of agriculture,' the dictum cannot be questioned, though under the circumstances of the continuous growth of wheat, as has been pointed out, conclusions indicated by the analysis of a crop happen to accord, at least approximately, with manurial practice.

Field experiments or demonstrations, which have been such a prominent feature of the educational work of the past decade, appear to have been first introduced at the meeting of the Association in 1861 by Dr. Voelcker.

While agricultural subjects have claimed a considerable share of the time of the Association, forestry has not been altogether overlooked. As early as 1838 we find attention being directed to what has of recent years come to be a burning question—namely, the maintenance of our timber supplies. At that early date, when the industrial development of the country was, comparatively speaking, in its infancy, the estimate of our timber requirements was, in the light of present experience, amusing in its modesty. Captain Cook estimated that '100,000 acres of waste taken from the Grampian Hills for the growth of larch would in two generations not only supply the ordinary wants of the country, but enable us to export timber.'[1] Assuming a rotation of eighty years, this estimate postulates that the produce of some 1,200 acres, of a value of about 120,000*l.*, was sufficient to make us independent of foreign supplies. Such is the estimate of 1838; now let us turn to the estimate of 1904. Dr. Schlich, in his volume on 'Forestry in the United Kingdom,'[2] passes in review Britain's timber requirements, and, after making allowance for woods like mahogany, teak, &c., which cannot be grown here, he comes to the conclusion that 'if all these items are added up we find that we now pay for imports in timber . . . the sum of 27,000,000*l.*, all of which could be produced in this country.' Assuming as before that the value of an acre of mature forest is 100*l.*, it means that our imports are drawn from 270,000 acres, and to maintain our supplies merely at their present level a forest area of more than 20,000,000 acres, worked on an eighty years' rotation, is necessary.

Although it has been reserved for the Cambridge Meeting of 1904 to witness the delivery of an Address from the Chair of an Agricultural Sub-section, this is by no means the first occasion on which an agricultural subject has furnished the theme for a Presidential Address. In 1880 the then Dr. Gilbert presided over Section B, and chose for his subject Agricultural Chemistry; in 1894 Professor Bayley Balfour inaugurated the work of the Biological Section with an Address on Forestry; while in 1898 the President of the Association focussed the vision of all thinking men on the greatest agricultural problem of all—the World's Supply of Wheat.

German Investigations on the Action of Conservation Agents on Farmyard Manure.

Those who have followed the progress of Agricultural Science in Germany must have noticed how much attention has been given during the past ten years to investigating the changes that take place in farmyard manure during storage under varying conditions. The stimulus and funds for this work have for the most part been supplied by the German Agricultural Society, which in 1892 resolved to carry through an exhaustive inquiry. For this purpose it enlisted the

[1] Cook, *On the Genera Pinus and Abies.*
[2] Bradbury, Agnew & Co., 1904.

co-operation of several of the most fully equipped stations in the Empire, and the reports that have appeared bear testimony to the industry and analytical ingenuity that have been brought to bear on this important subject.

The experiments were originally designed to extend over four years, the first, 1892–93, being devoted to preliminary, chiefly laboratory, experiments; the others, to work on a scale more in accordance with farm practice. But although the period originally contemplated is now long past, the problem is by no means solved, and the Society has recently been making a fresh grant for additional experiments of a similar character. In point of fact, the subject has been found to bristle with difficulties, and the results obtained with small quantities of manure, or in summer, have not always been confirmed with large quantities of manure, or in winter.

In 1897 I published an account [1] of the more important results obtained up to that time, confining myself chiefly to questions of temperature and the loss of organic matter, and the conclusion arrived at was that 'none of the conservation agents usually employed appears to have any very important influence on the decomposition of farmyard manure.'

Since then several important reports [2] have appeared, and I propose shortly to refer to their contents.

While the experiments have in almost all cases dealt with the fate of nitrogen, phosphoric acid, and potash, the chief interest centres round the nitrogen, for, given reasonably satisfactory conditions of storage, it is only this constituent of farmyard manure that is likely to suffer loss. But much importance, from the experimental point of view, attaches to the analytical results obtained with the other two substances, for the reason that the quantities of these found are the surest test of the accuracy of the work. The general method of procedure has been to employ a fairly simple but sufficiently nutritous food-mixture, and to allow a definite quantity of this and of litter for a certain number of selected cows. The weight of nitrogen, phosphoric acid, and potash in the food is accurately determined, all of which ultimately reaches the manure, less what goes into the milk, and into the live-weight increase, if any. If the account of what the animals receive as food and litter, and what they furnish as liquid and solid fæces, milk, and animal increase, approximately balances as regards mineral matter, it may be assumed that the sampling and analysis have been sufficiently accurate to justify definite conclusions being based on any deficiency in nitrogen that may be found.

The work of Hansen and Günther, Pfeiffer, and Immendorff was carried out at consecutive periods from 1893 to 1902, at the experimental station of Zwätzen, near Jena, where stalls and dung-pits had been constructed for the purposes of this research. Schneidewind's experiments were conducted at the station of Lauchstädt, near Halle.

Effects of Kainit.—This was used by Hansen and Günther at the rate of ·75 kg. per 1,000 kg. live weight of stock per day, while Pfeiffer and Immendorff used twice as much. The kainit was in no case spread on the litter in the stall, as this would have caused inflammation of the skin of the udder, legs, and abdomen of the cows, but was sprinkled on the manure as spread and pressed into the pits. In certain series of the experiments the manure was removed from the stalls daily, in others it was only removed once a week. Two weeks was the usual time necessary to collect a sufficient quantity of manure, which, with the liquids, usually amounted to about 8,000 kg. at Zwätzen, and about one-fifth of this weight at Lauchstädt. The period of storage was generally about four months.

Hansen and Günther found that in pits the untreated manure lost 11·5 per cent. of nitrogen; while the manure treated with kainit lost 14·4 per cent.

[1] *Journal Board of Agriculture*, September, 1897.

[2] Hansen and Günther, 'Versuche über Stallmist-Behandlung,' *Arbeiten der Deut. Land. Gesell.* Heft 30, 1898. Pfeiffer, 'Stallmist-Konservirung,' *ibid.* Heft 73, 1902. Immendorff, 'Ueber Stallmist-Bewahrung,' *Mitt. der Deut. Land. Gesell.* Heft 21, 1903. Schneidewind, 'Fünfter Bericht über die Versuchswirtschaft,' *Lauchstädt, Land. Jahrb.* xxxiii. p. 190.

Pfeiffer found that the loss of nitrogen in untreated manure was 17·2 per cent., which compares with a loss of 19·5 per cent. in the presence of kainit. The loss of nitrogen when kainit was used by Immendorff was 21·3 per cent., the loss in the untreated manure not being given in his tentative report so far available. Schneidewind did not experiment with kainit. The results of these experiments are in complete relative agreement, and show that the loss of nitrogen is greater when kainit is used than when it is withheld.

Effects of Superphosphate.—This substance was spread twice daily over the litter in the stall at the rate of ·75 kg. per 1,000 kg. live weight. The results obtained were as follows :—

—	Loss per cent. of Total Nitrogen	
	In untreated dung	When super. used
Hansen and Günther . . .	10·25	16·25
Pfeiffer	17·20	20·80
Immendorff	—	19·80

With superphosphate, as with kainit, the loss of nitrogen during the storage of dung has been increased. It may, however, be mentioned that Hansen and Günther and Immendorff found that superphosphate conserved nitrogen to an appreciable extent so long as the dung lay in the stall, but that its effects disappeared whenever its acid phosphate and free sulphuric acid had been neutralised by ammonia, and this rapidly occurred in the pit.

Effects of Precipitated Phosphatic Gypsum.—This at the rate of 1 kg. per 1,000 kg. live weight was tried by Hansen and Günther and Immendorff, the substance employed containing fully 8 per cent. P_2O_5. It was spread twice daily on the litter in the stall. The result obtained by Hansen and Günther was that after lying for seventeen weeks in the pits the manure that had been untreated had lost 10·35 per cent. of nitrogen, whereas that treated with the phosphatic gypsum showed a loss of 14·47 per cent. The loss of nitrogen found by Immendorff when this substance was used amounted to 19·8 per cent. This substance, like the others, would therefore appear to be valueless as a fixer of nitrogen.

Effects of Gypsum.—This substance has long been recommended as an agent for conserving nitrogen in the dung-heap. The results of its use, spread twice daily on the litter in the stall at the rate of 1 kg. per 1,000 kg., live weight, in the experiments conducted by Hansen and Günther, were that in the presence of gypsum the loss of nitrogen amounted to 11·89 per cent., which compares with a loss of 8·56 per cent. when nothing was mixed with the dung.

Schneidewind, using a much larger quantity of gypsum, namely, 5 lbs. per 100 lbs. of dung, found that the loss of nitrogen was reduced from 35·69 per cent. to 15·22 per cent. In this connection he says: 'The use of gypsum has markedly reduced the loss of nitrogen. Assuming the conserved nitrogen to have a good action on the crop, this agent may be said to have paid. But as the bulk of the nitrogen so conserved was found to consist of slow-acting albuminoid compounds, and seeing that the sulphate of lime was largely reduced to sulphides, which are directly injurious to plants, we cannot conclude that the use of gypsum has been profitable. Investigations with this substance will, however, be continued.'

Hansen and Günther carried their experiments the length of using the various lots of manure on crops, but this part of their researches was hardly more favourable to the use of conservation agents than the other. They thus express themselves: 'When the various manures were used on crops, five times in six the treated manure acted no better than the untreated. Only on one occasion was an improvement observable. Field and pit experiments alike have proved that the conservation agents employed are of no value.' Schneidewind expresses himself equally forcibly when he says: 'As the result of many experiments conducted by ourselves and others, we have arrived at the conclusion that chemical substances are valueless as conserving agents.'

Pfeiffer also tried sulphuric acid sprinkled over the manure as it was placed

daily in the pit, when it was found that the loss of nitrogen was reduced from 27·8 per cent. to 7·1 per cent. In this connection Pfeiffer says: 'The cost, however, was nearly a mark for each kilo. of nitrogen conserved, and the use of sulphuric acid is associated with so many drawbacks that its employment cannot be recommended.'

Schneidewind came to a similar conclusion, and thus expresses himself: 'As a result of numerous conservation experiments carried out with various quantities of sulphuric acid, and with various acid sulphates, we cannot advise the use of these substances.'

But although no benefits have been obtained from the use of the substances indicated, some useful information is available as to the advantages of giving attention in other directions to the management of farmyard manure. Hansen and Günther took four lots of manure of similar character, storing two of the lots in pits and placing the other two in heaps in the open field. From the end of September till the middle of December the pitted material had on the average parted with 13·25 per cent. of total nitrogen, whereas the loss in the manure in heaps averaged 25·3 per cent. When the behaviour of the ammoniacal nitrogen was investigated it was found that the loss was 35·73 per cent. in the pits and 82·5 per cent. in the heaps. The loss, therefore, is greatest in that part of the nitrogen which is the most active and the most valuable.

In another series of experiments by the same investigators the manure was all placed in pits, but in one case it was spread equally and trodden down, while the escape of liquids was prevented. In the other case the manure was simply thrown loosely and irregularly into the pit without spreading or treading, the surface being left uneven and therefore much exposed to the air, while the liquids were allowed to drain away. After lying for twenty-two weeks the loss of nitrogen was 15·76 per cent. in the pit containing the carefully treated manure, whereas in the other pit the loss amounted to 34·58 per cent.

Pfeiffer in a series of experiments proved that much of the nitrogen that disappears from manure is lost before the manure is transferred from the stall to the dungstead. He is strongly of opinion that stalls, boxes, and the like, should either be cleaned out twice daily, or, if the construction admits, the manure should be left to accumulate till it is some feet in depth, as in the system of management that prevails in cattle-courts and yards in this country.

The general conclusion arrived at, and clearly expressed by Pfeiffer, is that excessive loss in manure can be best avoided by storing it in a deep mass in a water-tight dungstead placed in a well-shaded situation, in which the material is firmly compressed. The necessary compression can be secured in various ways, perhaps most conveniently and effectively by means of the treading of cattle. The use of a considerable proportion of moss-litter is strongly recommended. This substance not only absorbs and retains the liquids, but, being acid, it fixes ammonia. In the absence of moss-litter, loamy soil rich in humus will prove a useful substitute.

The Chemical Fixation of Atmospheric Nitrogen.

It has for long been the dream of chemists to discover, or welcome the discovery, of a chemical process, capable of industrial application, by which the nitrogen of the air could be made available to replace or to supplement our rather limited supplies of nitrogenous manures. In his Presidential Address, Sir William Crookes had something to say on this fascinating subject, and looked hopefully to electricity to solve the problem. He pointed out that with current costing one-third of a penny per Board of Trade unit a ton of nitrate of soda could be produced for 26*l.*; while at a cost of one-seventeenth of a penny per unit—a rate possible when large natural sources of power, like Niagara, are available—the cost of such artificial nitrate of soda need not be more than 5*l.* per ton.[1]

Dr. von Lepel, in giving an account of recent work on this subject to the

[1] Crookes, *The Wheat Problem*, p. 47.

winter meeting of the German Agricultural Society in February of this year,[1] puts the cost of electric nitrate, as compared with Chili nitrate, in the proportion of 24 to 39, which is in close agreement with Sir William Crookes's estimate. Lepel points out that the material obtained, neutralised by some alkali, consists of a mixture of nitrate and nitrite. When used in pot-culture experiments it has given results closely agreeing with those furnished by Chili nitrate.

Good progress would also appear to have been made in another direction in the commercial fixation of atmospheric nitrogen, and a short account of the results was communicated by Professor Gerlach, of Posen, to the meeting of the German Agricultural Society already referred to, and is published in the same issue of the 'Mittheilungen.'

When air which has been freed of oxygen is conducted through finely disintegrated calcium carbide at a high temperature, one atom of carbon is displaced by two atoms of nitrogen, and calcium cyanamide ($CaCN_2$) is formed. This substance is also produced when a mixture of lime or chalk and charcoal is heated to a temperature of 2,000 deg. C. in a current of air.[2] When pure, this substance holds 35 per cent. of nitrogen, but in its crude commercial form it contains only about 20 per cent. Treated with acids, calcium cyanamide is changed into dicyandiamide, a substance holding nearly 67 per cent. of nitrogen, but directly poisonous to plants. Or, if heated in superheated steam, calcium cyanamide parts with all its nitrogen as ammonia, which, of course, is easily brought into a portable form.

But experiments conducted at Posen and Darmstadt during the past three years, both in pots and in the open field, have shown that calcium cyanamide itself is a useful nitrogenous manure, field experiments giving results about 20 per cent. below those obtained by the use of an equal amount of nitrogen in the form of sulphate of ammonia. In prepared soil in pots the results fully surpassed those obtained both with nitrate of soda and sulphate of ammonia, the less satisfactory yields obtained in the field being perhaps due to the organic acids inducing the formation of a certain amount of the poisonous dicyandiamide.

So far as one may judge from the information available, it would appear that agriculture will not have long to wait till it is placed in the possession of new supplies of that most powerful agent of production, nitrogen, and Sir William Crookes will see the fulfilment of his prediction that 'the future can take care of itself.'

Nitragin.

A few years ago much interest was excited in this and other countries by the announcement that the scientific discoveries of Hellriegel and Wilfarth had received commercial application, and that the organisms of the nodules of the roots of Leguminosæ could be purchased in a form convenient for artificial inoculation. The specific cultures placed upon the market were largely tested practically and experimentally, but the results were such as to convince even the patentees, Nobbe and Hiltner, that the problem which promised so much for agriculture had not been satisfactorily solved. Since that time, however, investigators have not been idle, and the present position of the subject is to be found in a recent Report by Hiltner and Störmer.[3]

It was early recognised that the organisms (bacteria) which inhabited the root nodules of the various species of Leguminosæ were not all alike, and that, in fact, they showed marked physiological if not morphological distinctions. Any particular species of leguminous plant is found to resist more or less successfully

[1] Dr. von Lepel, 'Neuere Versuche zur Nutzbarmachung des atmosphärischen Stickstoffs durch Elektrische Flammenbogen,' *Mitteil. d. Deut. Land. Gesell.*, 1904, Stück 8.

[2] Bull, *Imp. Inst.* June 30, 1904.

[3] 'Bericht über neue Untersuchungen über die Wurzelknöllchen der Leguminosen und deren Erreger,' *Arbeiten aus der Biol. Abteil. für Land- und Forstwirtschaft am K. Gesundheitsamte*, Band iii. Heft 3.

the attempt of these various organisms to effect an entrance into its root-hairs, and according to the power of the organism to gain access, and to establish colonies, so is the particular plant benefited and the stock of fixed nitrogen increased. This power of adaptability of the organism is designated its 'virulence,' a term, however, which is perhaps hardly suited to our English mode of expression, though it may for the present be retained. It has been found that organisms of what is called 'high virulence' are capable of entering with ease the root-hairs of vigorous plants at an early stage of their growth, and of inducing the formation of nodules that are large, numerous, and placed high up on the roots. Organisms of low virulence, on the other hand, can only enter plants of feebler growth, or plants that have passed the most vigorous stage of youth, so that the nodules, in this case, are small and scarce, and distributed, for the most part, near the ends of the roots. The practical object, therefore, would appear to be the breeding of strains or varieties of organisms of high virulence, adapted to the symbiotic requirements of the various important species of farm and garden leguminous crops.

The nitragin put on the market a few years ago was used in two ways, being either applied directly to the fields, or mixed with water and brought into contact with the seed before sowing. Under the former method of procedure an increase of crop was obtained only when the nitragin was used on land containing much humus. The explanation given for failure under other conditions was that the bacteria artificially introduced perished for want of food before the leguminous seed germinated and produced plants.

Failure of the nitragin to effect an improvement in the crop when it was sprinkled on the seed is now believed to be due to the action of secretions produced by the seed in the early stages of germination. These secretions are found to be rich in salts of potash, and when brought into contact with the bacteria in question they induce changes allied to plasmolysis, and these changes are subsequently followed by death. This difficulty was found to be got over by moistening the seed and allowing it to sprout before the nitragin was applied; but manifestly such a procedure would always be difficult, and often impossible, to carry out in practice. The object, however, would appear to have been gained in another way, namely, by cultivating the bacteria in a medium that imparts to them the necessary power of resistance. Such nourishment may take various forms, but that which gave the best results consisted of a mixture of skim milk, grape sugar and pepton, and it is in this medium that the organisms of the nitragin now distributed are cultivated.

Early in the present year the new nitragin was being offered free of cost to all members of the German Agricultural Society on the condition that it was used in accordance with the directions that accompany it. In consequence of the large demand the free offer was in April withdrawn, but the substance may be purchased from Professor Hiltner, of Munich, in quantities sufficient to treat the seed of a half to one acre at the price of one shilling. The United States Department of Agriculture are so convinced of the practical utility of the improved nitragin that they are distributing large quantities to American farmers. In this way the material will be thoroughly tried in two hemispheres under practical conditions, and abundant evidence should soon be forthcoming as regards its effects. It is to be hoped that British investigators will not be deterred by past disappointments from putting the new form of nitragin to the test.

Improvement of Varieties of Crops.

Speaking generally, the attention of agricultural investigators during the past fifty years has been directed more to manurial and similar problems than to the improvement of the yield of crops through the agency of superior varieties. This, it seems to me, is the outcome of the tradition that agricultural science is based upon chemistry, using the term in its old-fashioned and restricted sense, and as a consequence farmers have looked principally to the chemical laboratory for light and leading. It is true that much excellent work has been accomplished from the

botanical side, but this has been performed rather by farmers, seedsmen, or amateurs, than by trained botanists. But fortunately the botanist is now getting his opportunity, and the possibilities before him are sufficiently attractive.

Judging by the results that have been obtained, it would appear that wide divergencies as regards yield, nutritive qualities, resistance to disease, and other important properties exist between varieties of the same plant-species; so much so, in fact, is this the case, that attention to the relationship between variety and locality would appear to be one of the most important matters to which a farmer can give consideration. But it has been found that new varieties are frequently unstable, reverting rather rapidly to an unsatisfactory form, or displaying a lack of power of resistance to disease. It therefore becomes necessary constantly to be producing new varieties to take the place of those that are worn out, and it seems reasonable to anticipate that the professional botanist will take a much larger part in this work than has been the case in the past.

Not only is the yield of a crop greatly influenced as regards quantity and quality by the variety of seed employed, but, as is well known to practical farmers, the local origin of the same variety of seed has a marked influence on many properties of plants (vigour, resistance to disease, and resistance to frost, and to weather generally), and these properties quickly react on the yield. In this country we have a prejudice in favour of the seed of English-grown red clover, Provence Lucerne, Scotch potatoes, Belgian flax, Ayrshire ryegrass, pine and larch from Scotland, Norfolk and Cambridge barley, Warp-land wheat, &c., and there seems no reason to doubt that such preferences are based upon sound experience. This subject would appear to be one that is still full of interesting and important possibilities, and last year I had the opportunity of seeing some striking results in a new and unexpected direction. During the past few years the Austrian Experimental Forestry Station of Mariabrunn has given much attention to the influence of the local origin of the seed on the resulting trees, especially the common spruce, and, although it is still too early to pronounce a final judgment on the results, these are already so conspicuous as to warrant my placing some figures before you.[1]

In the autumn of 1896 a supply of seed was obtained from certain definite localities, the trees that yielded it being of varying dimensions and situated at various altitudes. The seed was sown in the spring of 1897 in the nursery attached to the station, and, having been transplanted into lines, a portion of the young trees are growing there now. Others were, in 1899, planted out in a wood (Loimannshagen) in the neighbourhood. In the autumn of 1902 the young trees were carefully measured, with the following results:—

Locality of Origin of the Seed	Height above Sea-level of the Mother-tree	Average Annual Height-growth of the Mother-tree	Average Height (1902) of the Young Trees		Average Growth in Height of the Nursery Trees in 1902
			In the Wood	In the Nursery	
	metres	cm.	cm.	cm.	cm.
Piesendorf, Salzburg .	1400	24	62	85·2	34·7
" " .	1750	14	47	61·6	23·3
St. Andrä in Kärnten .	1420	25	57	71·1	27·1
" "	1625	18	41	51·2	18·4
" "	1650	15	35	39·1	14·2
Treibach, Kärnten .	900	28	56	81·6	30 7
" "	900	29	53	80·9	29·7
Achenthal in N. Tyrol	900	31	64	87·9	29·0
" "	1300	28	67	80·5	27·9
" "	1600	26	50	62·2	21·8

[1] *Programm der vierten Versammlung des Internat. Verlandes Forstlicher Versuchsanstalten zu Mariabrunn*, 1903, p. 47.

These figures show—

1. That where, in any particular locality, mature trees were measured at different elevations, the tallest trees, as was to be expected, were found at the lowest elevation.

2. That where the seed of such trees was sown the height of the resulting trees, at the age of six years, was in close relationship to that of the mother-trees.

3. That where mother-trees of approximately equal height from the same locality and the same elevation (Treibach) were selected, the resulting progeny were also of approximately equal vigour.

The differences in the height-growth of the young trees are so striking as to lead to the conclusion that the financial returns of Forestry operations may be profoundly modified by the origin of the seed, and it would apparently pay nurserymen and planters well to give their careful attention to this subject.

Joint or Co-operative Work.

In conclusion, I may be allowed to call your attention to a prominent feature of experimental or demonstrational work which is found to exhibit itself in all countries of the world where serious attention is given to the improvement of agricultural production. While, no doubt, it is the individual who plants the germ of a new idea and fosters its growth till it is fairly established, it is by systematised co-operative effort that the practical value of the idea is tested, and that the knowledge is made available and acceptable to the workaday farmer. Various objections have been urged against field experiments, and it need not be denied that they are incapable of supplying a satisfactory answer to many scientific questions. Such experiments are exposed in no small degree to the disturbing influences of inequalities of soil, irregular cultivation, the attack of animals, and the vicissitudes of climate; but when reasonable precautions are taken to guard against these, and given a sufficient number of tests, the results of field trials are of the highest value as a guide to practice. Apart from attention to the preliminary details of the scheme, and to care in carrying it out, the main point to aim at in field-trials is to have them so frequently duplicated or repeated that the disturbing factors inseparable from field-work will be largely eliminated. Such duplication may take the form of repetition of the same test on the same area year after year, when one obtains some such series of results as those that have helped to make the reputation of Rothamsted. But however convincing may be the results of a series of experiments that have marched majestically on for half a century, they lack attractiveness for the investigator who desires to solve not one but many problems during his lifetime. For him, therefore, duplication in time gives place to duplication in space—in other words, he secures the same end, or an end that is in many respects equivalent, by repeating the test at several places in the same season, or in a short series of seasons. This method of work is, of course, by no means new. It was utilised with great advantage by the late Dr. Voelcker, and by our more recently departed friend Dr. Aitken, and it is a line that is still being followed by the two great societies with which these distinguished workers were so long associated. The method is also being practised extensively, chiefly through the agency of societies, in Germany, France, and other European countries, and it has taken firm hold in the United States and in some of our colonies. One of the largest and most successful agencies in co-operative demonstrations is to be found in Canada, where, during the past nine years, an average of 37,000 farmers have annually received small parcels of improved seeds through the Government experimental organisation directed by Dr. Saunders. It is claimed that the financial results to the country as a whole run to many millions of dollars, and there seems to be no reasonable doubt as to the accuracy of the statement.

I trust you will pardon my referring in this connection to a matter that is personal to a considerable proportion of this audience, and saying that, in my

opinion, one of the best pieces of work that has been done in this country in recent years is the preparation of the scheme of joint experiments by the Agricultural Education Association. The problems set for solution under that scheme are of the simple, direct, practical kind that field-work is thoroughly qualified to deal with. But the essence of success lies in the power of numbers, and the control of this factor rests with the members of the Association themselves. Now, most of the members of that Association are not only investigators but also teachers, and many of the institutions that they represent have recognised the advantages of keeping in touch with their past pupils through the agency of collegiate Associations. These old students, it seems to me, represent a large mass of most valuable material for carrying through co-operative experimental work of the class referred to, and I am convinced that the agriculture of the country would benefit in no small degree were this powerful agency fully utilised.

The following Papers were read:—

1. *The Organisation of Agricultural Research in America.* *By* Professor Atwater.

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2. *The Improvement of Wheats and Mendel's Laws.* *By* R. H. Biffen, *M.A.*

In the past many attempts have been made to improve our farm crops by resorting to hybridisation in the hope that some valuable character in a variety otherwise worthless might be transferred to a better variety. In some cases results of great value have been obtained, but in others the complications have been too great, and unfixed varieties have found their way into commerce, whilst in other cases skilled observers have stated that the problem of obtaining fixed types was hopeless.

The whole work, however, has been simplified by a knowledge of the principles established by Mendel, and now in place of the former chaos we can even predict years ahead the results to be obtained from a given cross, and isolate the required fixtures in the second or at all events the third generation. To accomplish this a detailed study of each crop will be essential. The experimental work will probably follow along the same lines for most crops, so that the case of wheat now to be described may, for the time at all events, be taken as typical of the experiments necessary in the case of our other crops.

On crossing two varieties, A and B, the resulting plants are all similar. The same is true whether A or B is the female parent, and consequently B or A the male. Some of the characters shown by the hybrid may be present in one parent, some in the other. Characters appearing in this generation Mendel described as 'dominant,' those which do not appear as 'recessive.' There is no particular virtue in a character being dominant or recessive.

In wheat the more important dominant and recessive characters are:—

Dominant.	*Recessive.*
Lax ears.	Dense ears.
Beardless ears.	Bearded ears.
Rough chaff.	Smooth chaff.
Grey chaff.	White chaff.
Red chaff.	White chaff.
Red grain.	White grain.

The seeds from the hybrid are then sown and produce plants, some of which show all dominant characters, some dominant and recessives, and some recessives only, in proportions readily deduced from a consideration of Mendel's laws. The

plants showing recessive characters only are fixed once for all; the others may or may not be fixed, but a subsequent trial of, say, fifty seeds from each form is sufficient for a test. If the progeny consists of various forms it may be neglected. The fixtures are then grown on for field and milling tests.

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3. *Hybridisation of Cereals.* *By* JOHN H. WILSON, *D.Sc.*

The author described experiments with oats, wheat, barley, turnips, potatoes, &c. The experiments with oats are in their fourth season. The crop now ripening represents the second generation from the hybrids. Certain white varieties were crossed one with the other, and also black ones with white. The hybrids of the latter are of most interest. They showed decided intermediate characters, the ears partaking of the one-sided form and the grains the black colour of the Black Tartarian used. The brown hybrid grains produced a crop of plants which bore pyramidal or open-headed as well as one-sided panicles, and white grains as well as black ones. The damage done to the crop by storms was so great that it was found impossible to say for certain what the proportion of pyramidal to one-sided panicles was. The colour of the grains, however, could be worked out. It was obvious that the colour of the grains is a character to be relied on, and if a sufficiently large number of plants be taken into consideration this character will be found to exhibit distribution in accordance with Mendel's law. The assumption can fairly be made that, if the condition of the crop had permitted, other characters, especially the form of the ear, would also have been found to conform to the above law.

The following table shows the ratios of black to white grains:—

	Grains sown.	Plants saved.	Black grains.	White grains.	Ratio.
Goldfinder ♀ Black Tartarian. ♂—					
	1,000	567	433	134	3·23 : 1
	900	566	415	151	2·75 : 1
Black Tartarian × White Canadian—					
	890	532	379	153	2·48 : 1
Black Tartarian × Abundance—					
	600	274	209	65	3·21 : 1

The plants bearing black grains were separated from those bearing white, and grains were selected from many single plants of each kind and sown in rows of 50 or 100 each. The crop produced by these is, at the time of writing, too green to admit of notes regarding colour of the grain being made, but the form of the ears can be observed in a general way. Pyramidal and unilateral ears occur in all the six plots sown with the black and white grains of the three hybrids, but there is a decided majority of one or other form in each plot. The general appearance of the plots justifies one in summarising as follows with regard to the predominant form of the ears:—

	Colour of grain sown.	Form of green ear.
Goldfinder × Black Tartarian	Black	Unilateral
	White	Unilateral
Black Tartarian × White Canadian	Black	Pyramidal
	White	Pyramidal
Black Tartarian × Abundance	Black	Pyramidal
	White	Pyramidal

It may be assumed that if the ears could have been studied last year it would have been found that the same condition as shown above obtained, and that the Black Tartarian, although dominant in all cases in respect of the colour of the

grain, was not so where the form of the ear was concerned. So far as has been observed, there is likelihood of the white forms of the series conforming to theory by continuing to produce white (recessive) ones only. It remains to be seen whether the black forms will vary in the manner required by Mendel and produce a stated proportion of white ones.

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4. *The Clover Mystery: a Probable Solution.* *By* ROBERT H. ELLIOT.

The great uncertainty of the clover crop is noted. The following experiment throws light on the most common cause of failure.

One half of a field was sown with a mixture of grasses and clovers purchased locally, and the other half with a similar mixture bought from an English seedsman. On both halves the clover plant was equally good after harvest, but by the following spring *every plant* from the seed locally supplied failed, while the clover from the English seedsman was still vigorous. Reasons are given to show that such a total failure after the clover has successfully come up must be owing to the seed having been obtained from an unsuitable climate.

Where the failures are partial it is shown that these are mainly owing to the presence of rye grass, and partly to six minor contributory causes, the details of which are given.

For the most economical and uniformly successful growth of the fullest clover crops three things are mainly necessary: (1) seed from a suitable climate; (2) land deeply supplied with humus, and deeply tilled, with the agency of the system pursued at the Clifton-on-Bowmont demonstration and experimental farm; and (3) the exclusion of perennial rye grass, or its use in small degree. With these conditions and general good management an increase of at least 25 per cent. may be obtained over crops grown under ordinary circumstances, and that, too, without any manure being used excepting, perhaps, some artificials with the turnip crops of the rotation. Evidences from an upwards of twenty-five years' experience on a large scale are given to show that if rye grass is excluded, or used in small proportion, and suitable clover seed sown, fair crops of clover can be generally relied on, and that the extensive failures that often occur are owing partly to the seedsman and partly to the farmer.

Evidences are given to show that the failure of crops generally, and especially from over-wet or over-dry seasons, is mainly owing to humus deficiency in the soil.

FRIDAY, AUGUST 19.

The following Papers were read:—

1. *On the Problems of Ecology.* *By* Professor A. G. TANSLEY, *M.A.*, *F.L.S.*

Ecology may be defined as the study of those relations of plants to their environment dependent on geographical and topographical factors. The author pointed out that the diversity of vegetation on the earth's surface is an ordered diversity, in which aggregates can be distinguished owing to definite, though often extremely complex, causes. It is very largely with *topographical aggregates*, due to soil, water, and other local conditions, that ecology has to do. The study of these topographical aggregates, or *plant-associations*, falls into two parts, corresponding with the two necessary stages of all scientific investigation, the *descriptive* and the *experimental*. It was shown that the first of these, which largely takes the form of ecological survey and the construction of maps of vegetation, is both a necessary and a valuable part of the study, since problems are revealed, and their solution often indicated at least, in the course of field-work, which would not be suspected by the experimenter in his laboratory and garden. Attention was called to the danger of wasting time and energy over trifling features, and was

found to be often due to our present ignorance of what is important and what is not. Finally, it was pointed out that the most certain way to obtain information in what may be described as the higher branch of ecology, *i.e.*, the detailed investigation of the functional relations of plant-associations to their surroundings, is the establishment of experimental stations in regions characterised by definite and specialised floras.

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2. *Botanical Survey of Britain.*[1] *By* W. G. Smith, *B.Sc., Ph.D.*

Knowledge of the ecological aspect of the British flora is imperfect when compared with recent progress in ecology; a general survey of the chief plant-associations of Britain has so far revealed some broad principles of distribution in relation to soil and climate. When wider areas are investigated the chief plant-associations will be known, and their occurrence as climatic, edaphic, or biological formations may be defined.

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3. *Observations on the Biology and Distribution of Woodland Plants.* *By* T. W. Woodhead.

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4. *Interglacial and Postglacial Beds of the Cross Fell District.* *By* Francis J. Lewis, *F.L.S.*

In the older peat deposits at different altitudes in Great Britain we have vegetable remains dating back to the glacial period, and much of the bottom layers of the low level peat mosses belong to the period of local ice sheets in Scotland. The glacial clay itself is in some cases traversed by peat beds of varying thickness, and the plant remains are of considerable interest as throwing light upon the duration and climatic conditions of the several glacial and interglacial periods. The plant remains of the postglacial peat also show that considerable fluctuations have taken place in climate since the close of the glacial period. So far little has been done in the way of systematically working out the plant remains in the peat mosses of Scotland and the peat beds which in some districts traverse the glacial clay. An examination by means of borings and sections is now being made of the larger peat mosses by the author of this paper with the aid of a Government grant from the Royal Society.

The present note deals with some remains in the peat of the Cross Fell district in Cumberland which have been found in the course of a botanical survey of that district.[2]

The sections described below are situated on the eastern slopes of Cross Fell at an altitude of 2,350 feet, near Slate Sike. The total thickness of the peat at this place is about 12 feet, resting upon 4½ feet of glacial clay.

The beds are described, starting from the base of the glacial clay upwards.

The base of the clay is composed of a mass of broken shale and sandstone mixed with stiff grey clay and merges above into very stiff blue clay containing only a few stones, most of which are fragments of shale.

The first interglacial peat layer occurs about a foot above the base of the clay, and consists of dry brittle peat much compressed and about 3 inches in thickness, and very sharply marked off from the clay both above and below. The plant remains from this layer have only yielded so far quantities of one or two mosses, such as *Camptothecium nitens*, *Hypnum sarmentosum*. No remains of Phanerogams have so far been found in this layer.

In the clay and about a foot above the first bed a second peat layer occurs. This second interglacial layer is 3–4 inches in thickness, and consists of the much

[1] Published in the *Scottish Geographical Magazine*, December 1904.

[2] 'Geographical Distribution of the Vegetation of the Basins of the Rivers Eden, Tees, Tyne, and Wear,' by Francis J. Lewis, *Geographical Journal*, March and September 1904.

compressed remains of mosses with numerous fragments of Alpine willows. The following plants have been recognised:—*Salix reticulata*, L., *Empetrum nigrum*, L., *Hypnum fluitans*.

The character of the peat differs from layer 1, as a fine sandy silt occurs here mixed with the moss remains.

A third peat layer runs through the clay about a foot above the second layer, made up of mosses, *Salix herbacea*, *S. reticulata*, and a few *Empetrum* stems. The upper surface of the clay is reached a few inches above the third peat bed.

A well-marked layer of Arctic plants rests upon the surface of the clay, the following species having been recognised:—*Salix reticulata*, L., *S. herbacea*, L., *S. Lapponum*, L., *S. Myrsinites*, L., *S. Arbuscula*, L. Numerous *Empetrum* stems are mixed with the willow remains.

The whole section above this layer consists of compact peat, and no further clay occurs. The peat, however, is not of the same character throughout. Above the Arctic plant bed the peat is chiefly composed of *Sphagnum* remains, and this passes upwards into a well-defined layer of shrubby willows, the stems being about 1–3 inches in diameter. Above this *Sphagnum* peat is again encountered for about 2 feet, yielding to a second layer of willow. This is overlaid by *Sphagnum* peat mixed with *Carex* sp. and *Eriophorum* remains. About 2 feet below the present surface of the peat abundant remains of the rhizomes of *Sedum Rhodiola* occur. The presence of this plant in such quantities near the surface of the recent peat is of interest, as it is only found very sparingly at the present day on the Pennines at Highcup Gill and Cronkley Scar. The present surface of the peat shows signs of rapid and extensive denudation. *Sphagnum* is almost absent from the district, and no peat appears to be forming at the present time.

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5. *Plants of the Northern Temperate Zone in their Transition to the High Mountains of Tropical Africa. By* Professor A. Engler.

In building up theories of the evolution of species, those types which are either fully identical or appear as closely allied forms in widely separated localities have always received special attention. There is a large number of cases of single or nearly allied species which are disjointedly distributed in a north-and-south direction across the Equator. Sir Joseph Hooker was the first to give a list of the so-called European types on Cameroon Peak. Now we know that many species of the same character have been found on the Kilimanjaro and other high mountains of tropical East Africa. In considering these plants the following questions must always be borne in mind:—

1. Are they identical with the forms living in other latitudes, or do they show any small variation from them?

2. Is there any possibility of their having originated from a species which was once distributed throughout the intermediate area between the present localities, or in the lower regions, which has developed itself into identical or convergent highland forms in the higher regions? Or is it to be supposed that the seeds have been brought by birds or wind across so many latitudes?

3. What are the means of transportation of seeds and fruits?

4. What is the power of germination? Especially, how long are the seeds able to keep it?

5. How do the plants cultivated in Europe from tropical seeds compare with their closest relatives which are indigenous to Europe?

Experiments to answer questions 4 and 5 have not yet been instituted. But whatever the results may be, they will not unsettle the assumption of the close affinity of an African to a European plant when based upon morphological comparison.

Regarding question 2, the answer is given for those plants which are isolated in the high mountains of Africa, whereas there are many closely allied forms in Europe. This answer is definitively settled in the case of those species whose

European forms belong to a larger group of related plants developed in Europe or in the northern temperate zone generally.

From these I shall select for discussion principally forms which, not being represented in Egypt, are to be found only in Abyssinia or further south.

1. Having carefully compared *Luzula spicata* (L.), DC., in a living state in different parts of Europe, and also the so-called *Luzula spicata*, var. *vimensis*, Hochst., in the Kilimanjaro, I come to the conclusion that the African plant must be separated, under the name *Luzula abyssinica*, Parlat, from the widely distributed *L. spicata*; that nevertheless the *Luzula abyssinica* has branched off from the *L. spicata*, which, passing to Abyssinia, suffered only few transformations; the inflorescence became erect, the basal axillary shoots were prolonged like stolons, and the cauline leaves became obtuse like the basal leaves.

2. Also, *L. campestris* (L.), DC., var. *Mannii*, Buchenau on Cameroon Peak, and *L. Johnstonii*, Buchenau, which must have branched off from *L. Forsteri*, show deviations from the European types in the same direction as *Luzula abyssinica* from *L. spicata*.

3. *Anthoxanthum nivale*, K. Schum, growing on the Kilimanjaro in two forms at 2,700 m., above sea level, and from 3,700–3,900 m., near melting snow, can only have branched off from *A. odoratum*, which in Africa is only to be found in Algeria, and, a little transformed, in Uluguru; the plant has taken a peculiar course of development under the climatic conditions of the upper Kilimanjaro.

4. *Koeleria cristata* (L.), Pers, is absent from the lower regions of tropical Africa, but it is to be found in Abyssinia, on Kilimanjaro, and the Cameroon Peak; on the Kilimanjaro up to 4,500 m. We see, again, a plant which, having reached Africa from Europe, appears in varieties and forms somewhat different from those produced in Europe.

5. *Arabis albida*, Steven, which came from Southern Europe to Abyssinia and the Kilimanjaro, is there extremely variable in size of stem and in form of leaves from the forest region upwards nearly to the uppermost limit of siphonogamic vegetation.

6. *Subularia monticola*, A. Braun, in the highest parts of Abyssinia and close to the melting snow of the Kilimanjaro, is most nearly related to *S. aquatica*, L., in Europe.

7. *Stenophragma Thalianum* (L.), Alak, has been very much modified in size in Abyssinia and on the Kilimanjaro.

8. *Cerastium caespitosum*, Goldb., shows many modifications in the high mountains of Africa.

All the species mentioned so far are closely allied to plants widely distributed in Europe, or more generally throughout the northern temperate zone of the Old World, growing there in the lower as well as the upper regions, whereas in Africa they are to be found only in the upper or uppermost belts. I think that immigration took place at some earlier date, during the pluvial epoch assumed by geologists. The differences to be seen in most of these highland forms, as compared with their relatives of the northern temperate zone, are always in harmony with the different climatic conditions. The highland flora of tropical Africa is not very rich in peculiar components derived from types of the lower regions. This, again, is the cause of the enormous extension of a few species and the amount of yet tenantless ground in the upper regions. Such ground has been always at the disposal of any seed brought by wind or birds as long as it kept its power of germination.

I may also be allowed to refer to some species of the forest region of tropical Africa which, being likewise nearly allied to those of the temperate zone, have undoubtedly not reached tropical Africa by man's intervention, viz., *Sanicula europæa*, var. *elata* (Hamilt.), Hook. f.; *Sambucus ebulus*, L., var. *africanus*, Engl.; *Veronica afrochamædrys*, Engl.; *Veronica abyssinica*, Fresen.

Further, I would mention the interesting fact that the well-known *Populus euphratica*, Olivier, of the Mediterranean region (in the broadest sense), has nearly reached the Equator, and has produced there the peculiar large-fruited sub-species *Denhardtiorum*, Engl.

In conclusion, I should like to add to the above-mentioned cases others of disjointed distribution which seem to be the result of other evolutions than those of the species considered so far: *Canarina abyssinica*, Engl., from Gallaland; *C. Eminii* Aschers, from Ruwenzori mountain; *C. campanula*, Lam., of the Canary Islands; seem to indicate that *Canarina* is an older genus, whose species, having travelled in more remote periods, may have formerly had wider areas; perhaps it was indigenous even to the Mediterranean region, like the genus *Sempervivum*, sect. *Aconium*.

With regard to the species or varieties I have enumerated, I may be allowed to make a general remark. One can call such modifications adaptations, but only in this sense, that the adaptation is a passive one, caused by the physical conditions of the climate; not an active one, corresponding to Lamarckian views.

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6. *Mechanical Advantage among Plant Organs.* *By* J. Clark, *Ph.D., B.Sc.*

Experiments with the asymmetric leaves of certain Commelinaceæ plants confirmed the view (first published by Spencer and endorsed by Goebel) that light is a factor in bringing about their asymmetric form. Closer examination, however, showed me that difference in light intensity is a very improbable explanation of this asymmetry, especially as by careful measurement another explanation presented itself, in which light is an indirect factor.

It became evident that the asymmetric leaves (which only occur on dorsiventral shoots) are differently placed with regard to the stem which bears them, from those on radial shoots whose leaves are quite symmetric. The former, in fact, undergo a twist, whereby one side of the leaf is drawn towards the stem, thus bringing about a 'hemmage' of the sap current to that side of the leaf. By excluding the light factor, it is possible to obtain symmetric leaves on dorsiventral shoots, for in this case no leaf-twist takes place.

Wider Application of the Mechanical Advantage Hypothesis.

1. *Other cases of Asymmetry* (Begonia leaf for example) are clearly explainable by the above view, for the larger side of leaf is always most directly continuous with the leaf-stalk.
2. *Anisophylly.*—The upper leaves on many plagiotropous branches are smaller than the lower leaves, because, while obtaining a favourable light position, the former must twist into an angle of disadvantage with regard to the sap current.
3. *Abnormal Palmate Leaves.*—The leaflet in most direct communication with the petiole is in the most favourable position for growth.
4. *Mr. Zeleny's experiment* with palmate leaves.
5. *Illustration* showing the probable *origin of peltate leaves* through rotation of leaf lamina into a position at right angles to its petiole.
6. Substitution of a main by a side shoot.
7. The *double-U form* obtained by gardeners.
8. Preference of *side roots* for *convexities*.

Besides offering a very probable explanation of many interesting phenomena in plant life, weighty evidence is brought forward against that view of plant growth and its relation to plastic substances which recognises a mere 'wandering of plastic substances,' and endorses the view of Sachs when he says: 'Die Anregung zu den Stoffbewegungen aber wird immer durch das Wachstum der jungen Organe gegeben; die Knospen eines Baumes treiben im Frühjahr nicht etwa deshalb aus, weil, wie die Leute sagen, der Nahrungssaft in sie eindringt, sondern gerade umgekehrt: die Nahrungsstoffe werden in Bewegung gesetzt, weil die Knospen zu wachsen anfangen.'

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7. *Exhibition of Pure Cultures of Algæ.* *By* Professor R. Chodat.

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8. *Exhibition of Micro-photographs of Freshwater* Plankton. *By* Professor G. S. WEST.

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9. *Exhibition of Kammatograph Photographs showing the Movements of Plants. By* Mrs. D. H. SCOTT.

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10. *On the Artificial Formation of a New Race. By* Professor G. KLEBS.

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11. *The Present State of our Knowledge of the Cytology of the Cyanophyceæ. By* HAROLD WAGER, *F.R.S.*

The Cyanophyceæ are in their cytological structure clearly marked off from all other groups of plants, with the possible exception of the Bacteria. The cell contents are differentiated into two distinct regions—a central colourless one (the nucleus) in which granules of various kinds occur, and a peripheral layer in which the colouring matters of the cell are contained. According to the observations of Hegler, and more recently of Kohl, the nucleus undergoes a true process of karyokinesis, and the colouring matters are contained in chromatophores.

In a recent paper[1] I have tried to show that the central body presents a sufficient number of nuclear characteristics to justify us in regarding it as a nucleus of a simple or rudimentary type, but I am not prepared to agree with Kohl that it produces true chromosomes and spindle fibres, or that it undergoes a normal process of karyokinesis similar to that which takes place in the higher plants. It seems to me to be a case of direct division, or at most a rudimentary karyokinesis.

The structure of the resting nucleus is not unlike that of the higher plants, in that it possesses a network with chromatin granules; but any one who examines it attentively with high powers cannot help seeing that it differs in other respects. It does not possess a definite nuclear membrane, and there is no true nucleolus. The network structure is not so clearly defined as the normal nuclei; it gives one the impression that it is more of a vacuolisation than a true network. In fact, we may possibly regard the nucleus of the Cyanophyceæ as produced by the vacuolisation of the central region of the cell (Butschli and Chodat), and the accumulation of chromatin granules therein; the fusion of the vacuoles and chromatin granules giving ultimately the appearance of a normal nuclear network.

In addition to the chromatin granules, we find inside the nucleus granules of another kind, called by Butschli the 'red granules.' They were first of all seen by Zacharias, and called by him the 'central substance.' Their exact nature is not known, but they probably consist of some albuminous substance produced by the activity of the nucleus, and may represent either a reserve substance or a stage in the production of chromatin, or possibly a waste product. They contain phosphorus, and stain deeply in nuclear stains.

Outside the nucleus, distributed irregularly in the cytoplasm or forming regular rows on the transverse walls, are the cyanophycin granules. These have characteristic reactions of their own, and are probably of the nature of albuminous reserve substances. In some cases they give a reaction for phosphorus, and appear to stand in close relationship to the activities of the nucleus.

The cell also contains glycogen, often in very considerable quantities. There is some evidence to show that this is produced as a result of assimilative activity. It is always abundant in a good light, and disappears in the dark.

The colouring matters are contained in small granules in the peripheral cytoplasm. They are considered by Hegler and Kohl to represent the chromato-

[1] *Proc. Roy. Soc.* 72, 1903.

phores of the higher plants, but it appears to me that they are rather to be compared to the 'grana' which are found in the chloroplast, than to the chloroplast itself.

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12. *The Virgin-woods of Java. By* Dr. J. P. Lotsy.

The two great forces which cause the character of these virgin-woods are moisture and light. By the former a number of hygrophilous leaf-structures are initiated. The author sees no reason to think that the hygrophilous structure of such leaves as *Platycentrum multangulum* and *Nephrodium callosum* are primitive to those genera; on the contrary, nearly allied species have leaves with a well-differentiated palisade- and sponge-parenchyma. It seems much more probable that these species are descendants of plants with a differentiated leaf-structure, which in some way or other entered the virgin-wood, and whose structure was modified by the moist atmosphere of the latter.

The author has no doubt that a good many of the characteristic features of the virgin-wood, as the large lenticels found on many twigs, the great number of aerial roots developed by branches of the most different species, *Cauliflory,* which occurs among the most different families, are the result of a direct action of the surroundings here of the moist atmosphere in the wood, in the same way as the formation of aerenchyma on the stems of *Lycopus europæus* when put in water is the direct result of the action of this water.

It seems of the utmost importance not to speak of adaptation, or of direct adaptation, in cases like these, as such terms are misleading, inasmuch as adaptation should embrace only such changes in the form or structure of a plant as are useful modifications. Or many modifications, either experimentally produced—and I need but mention such names as Goebel, Klebs, and Vöchting to bring before your mind a number of examples—or produced by Nature, need not be advantageous: they are frequently indifferent, or even harmful.

Curt Herbst has, in an interesting article published some years ago in the 'Biologisches Centralblatt,' shown the existence of a number of such modifications, which he calls hydromorphoses, barymorphoses, &c.; but it seems to the author that for all such cases one single collective term should be used, indicating *that the form of each individual plant is not a form innate to that plant, but is the result of that which Klebs calls its specific structure and the sum of all external circumstances which have acted upon it.*

Or, in other words, to put it in a drastic way, a plant has not *one* definite form caused by its specific structure (on the contrary, the latter allows it, as Klebs especially showed, a rather large variety of forms), nor is it at liberty to *choose* between a number of possible forms, but every individual has to take that form which external circumstances force upon it.

The form which an individual plant takes is consequently neither the only form which it could make under any circumstances nor a choice between a number of possible forms, but a form forced upon it, or, to use a Greek word: a BIAIOMORPHOSE.

It seems to the author that the introduction of this or an equivalent word would do good service, especially in making clear the opinions regarding direct adaptation and similar questions. In his opinion direct adaptation savours too much of teleology, and gives rise too easily to misconception, as if the plant thought out the consequences of the one or the other measure to prevent mischief, while the word biaiomorphose says nothing more than it means, viz., expresses the fact that the surroundings mould the plastic plant-body into the form which we see.

It seems, therefore, preferable to call such cases, as described above, cases of biaiomorphose, caused by the moisture of the virgin-wood, and to limit the word adaptation to those referred to below. The author thinks it highly probable that many useful structures have arisen accidentally as biaiomorphoses, together with a large number of useless or even harmful ones.

The latter, if sufficiently harmful, disappeared in the struggle for life; the former might either perish or remain along with the first. This would depend

on the intensity of the struggle, while if the struggle be very intense those biaiomorphoses which were from the beginning useful, although but accidentally so, will survive. These are the adaptations proper.

SUB-SECTION—AGRICULTURE.

The following Papers were read:—

1. *Analysis of the Soil by means of the Plant.* *By* A. D. HALL, *M.A.*

In view of the many difficulties attaching to the interpretation of soil analyses as a guide to the manurial requirements of the soil, attempts have been made from time to time to use the living plant as an analytical agent. It is well known that while the ash of a given plant possesses a characteristic composition, variations in the proportion of constituents like the potash or phosphoric acid will take place to a certain extent in response to the manuring. Investigations on the utility of the analysis of plant ashes to ascertain the needs of the soil for specific mineral manures have been undertaken by Heinrich, Helmkampf, and others, and particularly by Atterberg, who used oats as his test plant.

To try the agreement between this method and analysis of the soil, further experiments were begun in 1902 with oats grown in pots containing six soils of very different types. Although in certain striking cases both methods agreed in their results, there was no strict measure of consistency between the two sets of figures, while the variations between the material grown in duplicate pots of the same soil were often greater than that between different soils.

For further information the data accumulated in the Rothamsted experiments were consulted, and analyses of wheat, barley, mangels, and potatoes from certain of the plots were compared with the analyses of the soil of the same plots. In dealing with cereals it is necessary to examine the whole plant, the composition of the grain fluctuates but little with the manuring; any deficiency of a particular constituent will result in less grain being formed, while any excess will be left behind in the straw. From these Rothamsted results it seemed that though the composition of the plant did reflect that of the soil, yet the range of variation shown by the plant was less than that indicated by soil analysis. The ash of the root crops showed, however, a wider range of variation, and, in view of the greater sensitiveness of root crops to the lack of mineral plant foods as compared with the comparative indifference of the cereals, they seemed likely to prove better test plants to indicate the need or otherwise of specific mineral manures. Samples of potatoes, mangels, and of swedes were obtained during 1903 from experimental plots in various parts of the country, where the field trials indicated a reaction to phosphoric acid or potash manuring; analyses of the ash were made and compared with the analyses of the soil. The results indicate that the analysis of the ash of the swede plant would often provide a better indication of the phosphoric acid requirements of the soil than does the analysis of the soil itself, and that similarly the mangel plant will serve to test the state of the soil as to potash. A greater number of data as to the limits of normal variation in the composition of the ash are, however, wanted before the method can be employed for practically testing the soil.

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2. *The Probable Error of Agricultural Field Experiments.* *By* A. D. HALL, *M.A.*

Field experiments upon crops are subject to various sources of error: (1) errors incident to the operations of measuring the plot, applying the manure, &c., gathering and weighing the produce; (2) errors due to permanent inequalities of the soil brought about by differences in texture and composition, variations in the subsoil, drainage, &c., which errors again may vary with the season; (3) errors

due to temporary differences in the soil caused by previous inequalities of management or cropping, by the unequal incidence of pests and diseases, or by the individuality of the plants.

Of these sources of error, (1) diminishes with the skill of the experimenter and, to a certain extent, with the size of the plot; (2) can only be corrected by enlarging the number of the plots receiving the same treatment; (3) can be minimised by continuing the experiment for a sufficient number of years. The Rothamsted experiments afford several cases which enable one to estimate the magnitude of the errors (2) and (3), cases where there are two plots receiving treatment which is wholly or nearly identical, so that both plots are likely to be similarly affected by the season. The method adopted has been to reduce each year's results for the two plots to a uniform standard, taking the mean of the two plots as 100, thus eliminating seasonal fluctuations and giving each year the same weight in taking out a mean over the whole period. The results are plotted to show graphically the individual variations from the mean; the probable error of the mean result and the mean error of a single result are calculated by the method of least squares.

For example, taking forty-nine years' results of the two unmanured plots on the grassland mown for hay every year, the true means of the two plots are in the ratio 94·3 : 105·7, with a probable error of ± 0·8. The average deviation of a single year's result from the mean result for that plot amounts to ± 8·15. There is thus a permanent difference of about 11 per cent. in the yield of the two plots, due to differences of soil and situation; this represents the magnitude of errors (2). Putting the two sets together to represent the ideal unmanured plot we obtain a probable error of ± 0·67 in the mean result, and an average deviation of any single result from the mean of ± 9·9. As unmanured plots are subject to greater sources of error, the results of other manured plots were examined by the same method, with the following results:—

Crop	Size of Plots	Duration of Comparison	Probable Error of Mean Result	Average Deviation of Single Result from Mean
	Acre	Years		Per cent.
Hay . .	$\frac{1}{4}$	49	± 0·8	± 8·15
Wheat . .	$\frac{1}{2}$	52	± 0·6	± 6·2
Wheat . .	$\frac{1}{2}$	52	± 0·8	± 8·2
Barley . .	[illegible]	40	± 0·43	± 4·0
Mangels .	$\frac{1}{7}$	28	± 0·5	± 4·0

The observations are rarely numerous enough to permit of plotting the differences from the mean to see if they yield a normal curve of error. Other cases are discussed to ascertain the probable error when several plots are employed or the experiments continued over a short period; certain sources of error in the interpretation of the results of field experiments were also considered. In general, it is concluded that the probable error of any single plot result is not less than 10 per cent.

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3. *The Determination of the Availability of Insoluble Phosphate in Manures. By* T. S. Dymond, *F.I.C., and* George Clarke, *A.I.C.*

Many suggestions have been made in recent years for the use of a solvent for phosphatic manures which, while dissolving that part of the phosphate which is quickly attacked in the soil and available as plant food, leaves the remainder unacted upon. The two most largely employed solvents are a weak solution of citric acid, and a stronger solution of citric acid partly neutralised by ammonia.

The authors have had occasion to use both these solvents in the analysis of a large number of samples of basic slag (among other manures). They find that the phosphate dissolved by the acid ammonium citrate solution per cent. of total phosphate is generally lower the higher the percentage of total phosphate in the

basic slag. With the weak citric acid solution this is not the case, so that the results of the two methods of analysis are contradictory.

It is very remarkable that the weak citric acid solution dissolves more phosphate from basic slag than the acid ammonium citrate solution, although the latter contains more free acid. This is doubtless because citric acid contains one $=$COH.COOH group and two $-CH_2$.COOH groups; and the former group, being the more strongly acid, is the first to be neutralised by the ammonia. The acid ammonium citrate solution therefore acts as a solvent in virtue only of the $-CH_2$.COOH groups it contains, while the weak citric acid solution contains the stronger $=$COH.COOH group in addition. The former solution would therefore be likely to have a more *discriminating* action as a solvent, and to give analytical results of greater value as far as the availability of the phosphate is concerned.

The authors are not satisfied, however, with the use of the acid ammonium citrate as a solvent in analysis. In the first place it is extremely troublesome to work with, and in the second place it in no way resembles the solvents at work in the soil, the soil water being usually alkaline, not acid. The same two objections can be urged against the use of a solution of carbonic acid which the authors have tried but abandoned. The principal solvents in the soil are undoubtedly bicarbonates, and it therefore occurred to them to make experiments with these.

Of the bicarbonates of calcium, magnesium, sodium, potassium, and ammonium, the bicarbonate of ammonium solution is by far the best solvent for phosphate of lime. The following reaction probably occurs:—

$$Ca_3 2PO_4 + 8NH_4HCO_3 = CaH_4 2PO_4 + 4(NH_4)_2CO_3 + 2CaH_2 2CO_3,$$

whereas in the case of sodium bicarbonate probably no $CaH_4 2PO_4$ is formed, but a mixture of $CaHPO_4$ (insoluble) and Na_2HPO_4; and, at any rate, no complete solution can be obtained, however small the quantity of $Ca_3 2PO_4$ taken.

The presence of ammonium carbonate in the solution of ammonium bicarbonate does not influence its solvent action. Hence, the authors used in their experiments a saturated solution of the 'carbonate of ammonia' of commerce. That such a solution is far more convenient to work with than either citric acid or acid ammonium citrate is obvious, since it is only necessary after extracting a sample of basic slag with the solvent to filter and evaporate to dryness to get a residue of nearly pure phosphate and carbonate of calcium.

The analytical process adopted is as follows:—Digest one gram of the sample of basic slag with 200 c.c. of the saturated solution of 'carbonate of ammonia,' shaking from time to time, for twenty-four hours. The flask should be closed with an indiarubber cork, wired on to prevent loss of carbonic acid gas and precipitation of calcium carbonate. Filter, and wash the residue with cold water, evaporate the filtrate and washings to dryness, and determine the phosphate in the residue in the usual way.

A number of experiments made with various samples of basic slag showed that the quantity of phosphate dissolved was not appreciably increased either by increasing the time of digestion or increasing the volume of solvent.

The results of analysis of four samples of basic slag are compared with those obtained by other solvents in the following table:—

No. of sample of basic slag	Total tricalcic phosphate per cent. of slag	Tricalcic phosphate dissolved by acid citrate of ammonium[1] solution per cent. of total phosphate	Tricalcic phosphate dissolved by 1 per cent. citric acid solution per cent. of total phosphate	Tricalcic phosphate dissolved by saturated carb. of ammonia solution per cent. of total phosphate
1	25·94	91·6	92·0	40·9
2	30·00	89·3	91·2	40·4
3	36·15	80·3	93·4	40·4
4	43·10	84·6	86·3	40·2

[1] 150 grams citric acid and 27·9 grams ammonia in 1,000 c.c.

Further experiments are in progress.

4. *The Influence of Sulphates as Manure upon the Yield and Feeding-value of Crops.* *By* T. S. DYMOND, *F.I.C.*, F. HUGHES, *and* C. JUPE.

A determination of the sulphuric acid in twenty Essex soils showed that they contained on the average ·051 per cent. of SO_3, an amount hardly more than one-third the percentage of the phosphoric acid in the same soils. Even this small amount of sulphuric acid is by no means entirely in a soluble state. The extraction of a soil by a 1 per cent. citric acid solution yielded only one-eighth of that extracted by concentrated hydrochloric acid, pointing to the existence in the soil of insoluble basic sulphates. In the light of these results, it may well be asked whether the available sulphuric acid in soils is sufficient for crops; for, taking the average composition of ordinary farm crops, the sulphuric acid absorbed amounts to 25½ lbs. per acre, *i.e.* almost as much as the phosphoric acid, which amounts to 28 lbs.

Field experiments have been made in Essex upon the use of sulphate as manure for oats (two experiments), cabbages (three experiments), peas (two experiments), and permanent pasture. In the case of chalky soils the sulphate was applied in the form of gypsum; in the case of non-chalky soils in the form of sulphate of ammonium, as against chloride of ammonium. Except in the case of the cruciferous crop, the result was negative, the crops being more often decreased than increased by the application. In the case of the cabbages, *i.e.* the crop richest in combined sulphur, the application of sulphate increased the crop in each of the three experiments.

That with so small a quantity of sulphuric acid in the soil the crops yet find, as a rule, enough for their requirements is remarkable; but it must be remembered, in the first place, that rain-water contains an appreciable quantity of sulphuric acid, amounting in the case of a sample analysed at Chelmsford to 1 part per 100,000. This for the average annual rainfall in Essex during the years 1895–1903 (500,000 gallons per acre) amounts to 50 lbs. SO_3 per acre, or double the requirements of average farm crops. In the course of some pot-culture experiments it was found that maize, clover, vetches, oats, mustard, and peas, even when grown in sand washed free from sulphate by hydrochloric acid, failed to respond to sulphate-manuring when exposed to the rain, and it was only when kept under cover during rain and watered with distilled water that striking differences were observed.

In the second place, Berthelot and André have shown that the total sulphur in soils they examined amounted to nearly eight times the sulphur in the form of sulphate, the principal part of the sulphur being in the form of organic sulphur compounds. The present authors find that in the presence of fermentative organisms a fairly rapid oxidation of this organic sulphur takes place. A soil was sterilised by heating at 100° for 1½ hour on two successive days. One part was inoculated with soil-washings, the other not. Air, previously heated, was passed over both for 70 hours at the rate of 3 litres per hour. At the end of this period the sterilised soil contained ·0256 per cent. of SO_3; the inoculated soil contained as much as ·0339, an increase of ·0083 per cent., produced by fermentation.

The question now arises whether, although crops grown under ordinary conditions do not respond in yield to sulphate-manuring, the application of sulphate may not influence the composition and feeding-value, and especially the proportion of albuminoids, which are, as a rule, sulphur compounds. For this inquiry a long series of determinations have been carried out of the total albuminoid nitrogen and sulphur in crops grown with and without sulphate of lime in presence of abundance of chalk. The crops included vetches, mustard, and oats grown in soil in pots, oats, mustard, and vetches grown in sand in pots, and grass and clover grown in the field. The sulphur was determined by Berthelot and André's

combustion method; the nitrogen by the usual methods. The results of the whole series are averaged in the following table:—

—	Per Cent. of Total N.	Per Cent. of Albuminoid N.	Albuminoid N. per Cent. of Total N.	Per Cent. of S.
Sulphur applied . .	2·026	1·269	60·422	·403
No sulphur applied . .	1·754	1·130	63·333	·317

In every single case the percentages of total nitrogen and albuminoid nitrogen and of sulphur were increased by the application of sulphate as manure. The proportion of albuminoid nitrogen to total nitrogen varied; in the case of clover, grass, mustard, and maize it was decreased; and in the case of vetches and oats it was increased by the application of sulphate.

These results are remarkable, and may have an important bearing on the question of the frequently noticed differences in the feeding-value of pastures and root crops. Further experiments are being made.

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5. *The Improvement of Poor Clay Soils by White Clover and other* Leguminosæ. *By* Professor T. H. Middleton, *M.A.*

In the following table will be found some results obtained in six experiments on poor pastures in the counties of Northumberland, Cambridge, Essex, Northampton, Hampshire, and Norfolk. The figures give the increase in the live weight of sheep produced by the action of various manures on pastures. The soils in the first five cases varied from strong loam to clay, and the results are the average figures of three years. The Norfolk soil was sandy, and the figures for this station are averages for two years only:—

No.	Treatment per Acre	Average Increase over Unmanured Land per Acre per Annum for Three Years							
		Cost of Manure expressed in Pounds of Increase	Cockle Park, Northumberland	Hatley, Cambs	Yeldham, Essex	Oransley, Northants	Sevington, Hants	Trowse, Norfolk	Mean for Cockle Park, Cransley, and Sevington
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1	200 lb. phos. acid in basic slag	27	107	85	68	56	44	−5	69
2	100 lb. phos. acid in basic slag.	13½	41	64	30	28	28	—	33
3	100 lb. phos. acid in superphosphate.	19	42	57	18	25	35	−22 [1]	31
4	100 lb. phos. acid in superphosphate. 28 lb. nitrogen in sulphate of ammonia.	38	48	—	26	42	17	—	36
5	100 lb. phos. acid in superphosphate. 100 lb. potash in sulphate or kainit.	36	54	—	—	47	27	8 [1]	43
6	100 lb. phos. acid in superphosphate and 1 ton ground lime.	43	55	—	—	49	27	—	44
7	4 tons quicklime . .	64	2	—	—	14	4	—	6

[1] Plots 3 and 5 received 200 lb. phos. acid in superphosphate, and Plot 5 50 lb. potash in kainit

It will be seen that phosphatic manures have produced a large increase (Plots 1, 2, 3); that a nitrogenous manure has had little effect (Plot 4); that potash and lime in conjunction with phosphates have caused a moderate increase (Plots 5 and 6); and that lime by itself has had little effect, except at one station, where there was a moderate increase (Plot 7). It will further be noticed that in three of the five cases in which phosphates have proved beneficial the larger application of phosphatic manure has produced twice, or more than twice, the increase yielded by the smaller (half) quantity, although the latter would, in the opinion of farmers, be a liberal dressing. The normal action of manures is strictly governed by the 'law of diminishing returns,' and this exception indicates that the benefit produced by phosphates on the herbage is not of the direct or ordinary kind.

Inspection of the plots further shows that the immediate action of a phosphatic manure is on the *Leguminosæ* only, and that the marked improvement which gradually takes place in the gramineous herbage is due to the soil-improving qualities of leguminous plants.

Proof that phosphatic manures do not benefit the pasturage on poor clay soils in the absence of *Leguminosæ* is furnished by an experiment at Wenden Lofts in Essex. The soil was in every way adapted to the action of basic (phosphatic) slag, but as no *Leguminosæ* could be found it was surmised that slag would not improve the herbage. Some plots were marked off and manured with phosphates, potash, and lime alone, and in combination; on other plots white clover (*Trifolium repens*) was sown, and some of the sown plots were treated with phosphates. None of the manures produced any effect on the natural herbage. Where clover was sown on unmanured land it grew, but the plants were small and valueless. Where phosphates were applied, however, there was a luxuriant growth, similar to that found on the Cockle Park pastures after treatment with basic slag.

The failure of phosphates to benefit the Trowse pasture (see table) was not due to the absence of leguminous herbage, but to the dry character of the soil. Rapid growth and the benefits which follow it are impossible in the absence of a plentiful supply of moisture. Hence a marked improvement from phosphatic manures is usually seen only on medium and heavy soils. With a high and continuous summer rainfall light soils would, however, show improvement. Of ordinary *Leguminosæ, Trifolium repens* is by far the most valuable in improving the soils of pastures. When properly fed and supplied with moisture it is capable of developing at an extraordinary rate. It is especially luxuriant when growing in association with *Agrostis,* which shelters it in winter and makes way for it in summer. In the presence of grasses which form a close turf white clover grows comparatively slowly. Next to *Trifolium repens, Medicago lupulina* is probably most useful in improving poor soils. It grows very luxuriantly in damp seasons. *Trifolium minus* and *Lotus corniculatus* are also of considerable value. The latter has been very abundant this year. *Trifolium pratense* is most useful where it grows, but it does not cover the surface so uniformly as the others, and it disappears more readily.

The application of basic slag to pastures is now very common, but there have been no systematic attempts to utilise it in conjunction with white clover in such a way as to produce the maximum effects on the soil; and of the 9½ millions of acres now under pasture in England it is likely that at least two millions might be improved so as to leave a net profit of 5*s.* per acre per annum if the white clover plant were cultivated as skilfully as most of our farm crops are.

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6. *A New Method of Forming Nitrites and Nitrates.* *By* Edward John Russell, *D.Sc., and* Norman Smith, *M.Sc.*

Whilst studying the oxidation of phosphorus in moist air the authors observed that ammonium nitrite and nitrate are invariably formed in this reaction, even when both air and phosphorus are carefully purified beforehand. Other oxidations have now been investigated, and in a number of cases the reaction appears to be accompanied by a simultaneous oxidation of nitrogen of the air.

Hydrogen peroxide has long been recognised as a product of oxidation, but so far as the authors are aware the formation of nitrites and nitrates has not before been noticed.

The experiments have been carried out as follows:—A platinum dish containing the oxidisable substance and pure distilled water was placed in an empty desiccator, supported over a large dish of sulphuric acid and covered with a bell-jar to prevent free access of outside air. A second exactly similar apparatus was put up as a control, the platinum dish containing water alone. The two were allowed to stand side by side in sunlight for eight days and their contents then tested. The results obtained are set forth in the following table. It will be observed that on no occasion did the control experiment show the presence of either ammonia, nitrite, or nitrate.

Substance in Dish	Ammonia	Nitrite	Nitrate
Pure water	Nil	Nil	Nil
Iron	Some	Nil	Nil
Zinc	Some	Nil	Some
Magnesium	Some	Some	Little
Manganese chloride + sodium carbonate	Small quantity	Much	Some
Ferrous sulphate + sodium carbonate	Much	Some	Much

Negative results were obtained with tin, stannous hydroxide (stannous chloride + sodium carbonate), cuprous chloride, cuprous hydroxide (cuprous chloride + sodium carbonate), and tartaric acid.

Sunlight favours this autoxidation; it is doubtful, in fact, whether it takes place in the dark.

The reaction apparently goes on in soils. A soil rich in humus was washed to remove ammonia, nitrites, and nitrates as far as possible; it was then placed into the apparatus for a few days. All three substances were found to have formed in very distinct amounts.

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7. *The Chemical Composition of Different Varieties of Mangels.* *By* T. B. Wood, *M.A., and* R. A. Berry, *F.I.C.*

A considerable number of well-known varieties of mangels were grown on the University Farm at Impington, near Cambridge, on a medium loam soil, and at four stations in Norfolk, and one in Bedfordshire. Two seasons' crops have already been harvested and examined. Samples were taken in the form of horizontal cores through the greatest diameter of the root, and at least fifty roots were cored from each plot. The dry matter was determined by drying at about 65° C. to constant weight duplicate samples of fifty cores each. These were then ground and used for the determination of nitrogen by Kjeldahl's method (salicylic acid modification, as the roots contain nitrates).

The sugar was determined in the juice expressed from the pulped cores. The juice was first clarified with basic lead acetate, and then polarised, inverted by Clerget's method, and polarised again. It was found that in the autumn, when the roots were examined, the sugar was nearly all cane sugar with ·1 to ·5 per cent. of dextrose.

The two years' systematic examination shows clearly that mangels, leaving out a few new and peculiar varieties, may be divided into four classes, each with definite characters.

Group I.—*Yellow Globe.*—Yellowish skin, nearly white flesh; a very large cropper on all the soils on which it has been tried. Low percentages of dry matter and sugar; average percentage of nitrogen, less than one-third of which is proteid.

The various seedsmen's strains, such as Sutton's Prize Winner, Webb's Smithfield, Carter's Windsor, are all practically identical.

Group II.—*Golden Globe.*—Orange skin, deep yellow flesh; a very fair cropper on all the soils on which it has been tried. High percentages of dry

matter and sugar. Average percentage of nitrogen, about two-fifths of which is proteid.

The various seedsmen's strains are similar, but not identical either in appearance or composition.

Group III.—*Golden Tankard.*—Similar to the above in every point but shape. Contain slightly lower percentages of dry matter, sugar, and nitrogen, but rather more of the nitrogen is proteid.

The seedsmen's strains are again similar, but not quite identical.

Group IV.—*Long Red.*—Red skin, white flesh with pink rings; large cropper on sufficiently deep and good soils. High percentage of dry matter and sugar; low percentage of nitrogen, but about half the nitrogen is proteid.

On soils that suit it, Long Red gives more dry matter per acre than any other variety. The various seedsmen's strains appear to be identical.

The above groups include all the commonly grown varieties except the *Intermediates,* which much resemble the Golden Tankards, but are rather more spindle-shaped and lighter in colour, yield rather heavier crops, and contain rather smaller percentages of dry matter and sugar. In addition to the commonly grown varieties, three less well known ones were tried:—

Long Yellow, which resembles Long Red in shape and in chemical composition, but has a yellow colour and is a lighter cropper.

Crimson Tankard.—A distinct variety which has a tankard shape and the colour of the Long Red, but does not crop well on the soils on which it has been tried. It contains fairly high percentages of dry matter and sugar, about equal to the other tankards.

Sugar Mangel.—A hybrid between Long Red and the sugar beet, which contains a very high percentage of sugar and dry matter, but crops poorly, buries itself too deeply in the soil, and still splits into red, white and pink individuals.

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8. *Variation in the Chemical Composition of Mangels.* *By* T. B. Wood, *M.A., and* R. A. Berry, *F.I.C.*

During the last two seasons about 400 samples, each consisting of at least fifty cores, have been examined for percentage of dry matter and sugar, and in many cases nitrogen. In addition, the dry matter has been determined in about 1,000 individual roots, and the sugar and proteid and non-proteid nitrogen in 100. It has been found that very wide variation occurs, due to (1) variety, (2) soil and climate, (3) season, (4) manuring, (5) individuality. The extent of the variation in each case is briefly noted below.

Variety.—Taking, first, percentage of dry matter, the worst variety at each station in each season contained only about two-thirds as much dry matter as the best. A crop of 20 tons per acre of the best variety would therefore contain as much food as a 30-ton crop of the worst variety.

The variation in content of sugar and nitrogen is between much the same limits.

Soil.—Variation due to differences of soil and climate is considerably less; the ratio of the average percentages of dry matter in eight varieties at the worst and best stations is 100 : 114. The heavier soils gave roots of the better quality.

Season.—Seasonal variation appears to be smaller still, but neither 1902 nor 1903 were extreme seasons, so that greater variation may be met with in the future. The ratio of the average percentages of dry matter in all the varieties grown in both years is 100 : 109, the percentage being higher in 1902.

Manuring.—Only one series of experiments on this subject has been worked through, and the variation due to manuring in the ordinary course of farm practice appears to be quite small (100 : 107). Further work is necessary before anything definite can be stated.

Individuality.—It is when individual roots are examined that the greatest variation is found. Thus, in 200 roots of one variety, all grown side by side on the

same plot, the lowest percentage of dry matter was only 10·7, and the highest 19·7, the ratio being 100 : 184. In three other varieties the ratios came out 100 : 183; 100 : 184; 100 : 179.

The sugar and nitrogen vary still more widely. In 100 individual roots of one variety, grown side by side on the same plot, the following were the limits:—

		Ratio.
Highest percentage of sugar	11·0	100 : 190
Lowest percentage of sugar	5·8	
Highest percentage of nitrogen	·25	100 : 280
Lowest percentage of nitrogen	·09	

Throughout the examination of the individual roots careful records have been kept of the shape, size and colour of each root which has been sampled and examined. Shape and colour do not appear to be in any way correlated with any peculiarity of chemical composition. As regards size, a mixed sample from fifty large roots is certain to contain a lower percentage of dry matter and sugar than a mixed sample from fifty small roots of the same variety grown under identical conditions, but there is nothing like inverse proportionality between size of root and percentage of dry matter. Among the 1,000 roots examined many large ones have been found containing high percentages of dry matter, and *vice versa*. By saving such large roots with high percentages of dry matter for seed-mothers it should be possible to improve the race.

Again, there appears to be no definite correlation between percentages of dry matter, sugar, and proteid and non-proteid nitrogen. Each appears to vary independently of the rest. It should therefore be possible, by continuously selecting as seed-mothers roots of definite composition, to change the composition of the race in any desired direction. Experiments of this kind are already in progress on the University Farm.

MONDAY, AUGUST 22.

The following Papers were read:—

1. *On the Forms of Stems of Plants.* *By* LORD AVEBURY, *D.C.L.*, *F.R.S.*

Some plants have round stems, some square, some triangular, some pentagonal. No doubt there are reasons for these and other forms, but the author found no explanation in botanical works.

It is, of course, important for plants, as for architects, to obtain the greatest strength with the least expenditure of material. To do this it is necessary that the plant should be equally liable to rupture at every point when the strain is equal. If not, it is obvious that a certain amount of material may be removed from the strongest part without increasing the danger of rupture. If the stem of a plant, or any other pillar, is affected by pressure—say of wind—one side will be extended and the other compressed, while between them will be a neutral axis, and both extension and compression will be greatest along the surface farthest from the neutral axis. It follows, therefore, that the strongest form is where the material is collected as far as possible from the neutral axis. The two bars cannot, however, be entirely separate, and must therefore be connected by a bar or bars. This is the origin of the well-known girder (fig. 1).

If the forces to be resisted act in two directions at right angles to one another, two girders must be combined, one at right angles to the other.

If the forces act in all directions, a circular series of girders will be required, as Schwendener and others have pointed out. This is the case in the stems of trees, where the woody fibres form a ring, only separated in places by what are known as the 'medullary' rays. This is the reason for the prevalent round form of stems.

The question then arises, Why is this form not universal? As regards plants having quadrangular stems, it may be pointed out that when the leaves were

in opposite pairs, each pair at right angles to those above and below, as, for instance, in the dead nettle, the strain of the wind would be mainly in two directions, and the 'double girder' (fig. 2) would be the best form. If so we should expect to find quadrangular stems associated with opposite leaves. The author then took the British flora, and showed that plants with quadrangular stems always have opposite leaves, and that plants with opposite leaves have generally, though with exceptions, quadrangular stems. The reasons for these exceptions were then considered.

Passing to triangular stems, it was pointed out that they might be accounted for by the same considerations. Many Monocotyledons, but not all, have the leaves in threes. Sedges, for instance, all have more or less triangular stems, while in

FIG. 1.

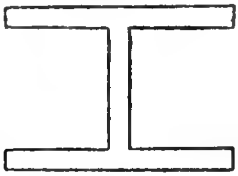
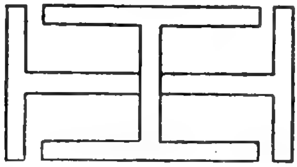


FIG. 2.



grasses they are round. Now, sedges have leaves in threes, while in grasses they are distichous, *i.e.* in two rows or ranks.

In plants with pentagonal stems the same relation prevails. The bramble, for instance, has a stem more or less pentagonal, and the leaves are in whorls of fives, a character, as he incidentally observed, which throws light on the number of petals and sepals. The petals represent a whorl of leaves, and as a rule, when the whorl consists of five leaves, the flower has five petals and five sepals; while when the leaves are opposite a whorl would consist of four leaves, as, for instance, in veronica, where also there are four petals.

Thus, then, the author finally remarked, plants have worked out for themselves, millions of years ago, principles of construction so as to secure the greatest strength with the least expenditure of materials, which have been gradually applied to the construction of buildings by the skill and science of our architects and engineers.

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2. *On Recent Researches on Parasitic Fungi.*
By Professor H. MARSHALL WARD, *F.R.S.*

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3. *On the Vegetative Life of some* Uridineæ.
By Professor JAKOB ERIKSSON.

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4. *On the Development of the Æcidium of* Uromyces Poæ, *and on the Life-History of* Puccinia Malvacearum. *By* V. H. BLACKMAN *and* Miss HELEN C. I. FRASER.

TUESDAY, AUGUST 23.

The following Papers were read:—

1. *Sunshine and* CO_2*-Assimilation: an Account of Experimental Researches.* *By* Dr. F. F. BLACKMAN *and* Miss MATTHAEI.

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2. *Struggle for Pre-eminence and Inhibitory Stimuli in Plants.* *By* Professor L. Errera.

Vegetable physiology, like animal physiology, presents a great number of cases of suspensory stimuli, or *inhibitory phenomena*: arrest of growth of the fructiferous filament of *Phycomyces* during the formation of the sporangium; influence of wounds on the growth, and irritability of certain organs (traumatic shock); retarding effect of light on elongation, &c. It is also in this way that the influence exercised by the apex of many plants on the subjacent ramifications with which it finds itself in some way struggling for pre-eminence can best be understood.

The apex of *Picea excelsa*, for instance, hinders the side-branches from rising geotropically. If one suppresses it, or if it is notably weakened, a conflict for supremacy obtains between the branches themselves; generally one of the branches nearest the summit, or the strongest among equidistant ones, prevails and forms a new summit. The apex continues to make itself felt even after the removal of a ring of bark; its action then probably proceeds through the living cells of the pith and the medullary rays. On the other hand, in the *Araucarias* (where the regeneration of the summit is effected by new buds, and not by the rising of already developed branches) the action of the apex is conducted by the bark, and an annular incision is equivalent to cutting off the top.

Several arguments can be quoted to support the existence of inhibitory stimuli emanating from the apex, and the production of 'suckers' (gourmands) and of 'witches' brooms' can be connected with it.

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3. *On the Proteases of Plants.* *By* Professor S. H. Vines, *F.R.S.*

As the result of observations made in the course of the last three years, of which accounts have been published from time to time in the 'Annals of Botany,' I have demonstrated the very general occurrence of proteases in all parts of plants.

With regard to the nature of the proteases, it has been ascertained, in the first place by means of the tryptophane-reaction, that their action is *peptolytic*—that is, that they decompose peptones and albumoses into non-proteid substances such as leucin, tyrosin, and other amido-acids. In no case was peptonisation observed without peptolysis; whence it follows that the proteases are not of the nature of pepsin, but rather correspond to either the trypsin or the erepsin of the animal body.

It has been found that in certain cases the juices or extracts of plants can peptonise fibrin, indicating the presence of a tryptic protease; but more commonly they do not possess this capacity. The following are instances of the peptonisation of fibrin:—

Pine-apple (juice); papaïn (solution); nepenthes (pitcher-liquid); yeast (extract); mushroom (extract); cucumber (juice); melon (juice); wheat-germ (extract); asparagus (juice); *Phytolacca decandra* (extract of leaves); fig (extract of leaves).

It may be inferred that a tryptic protease is present in these plants.

It is not necessary to give a list of cases in which peptolysis of albumoses and peptones (as contained in the commercial preparation known as Witte-peptone) has been observed; it appears that the juice or watery extract of almost any part of any plant can effect this process. Although fibrin is not digested in these cases, yet any proteid matter naturally present in the juice or extract is digested (*autolysis*). Hence it may be inferred that an ereptic protease is present.

I have found in the yeast and the mushroom that both a tryptic and an ereptic protease are present; no doubt other cases of such an association of proteases, analogous to that of the 'trypsin' of animals, remain to be discovered.

It may be stated generally that these proteases are most active at the natural degree of acidity of the juices or extracts.

It is, however, quite possible that the protease here described as 'tryptic' may be found to be a mixture of erepsin with a pepsin.

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4. *Sexuality in Zygospore Formation.* *By* Dr. A. F. Blakeslee.

1. The production of zygospores in the Mucorineæ is conditioned primarily by the inherent nature of the individual species, and only secondarily by external factors.

2. According to their method of zygospore formation, the Mucorineæ may be divided into two main groups, which have been termed respectively homothallic and heterothallic.

3. In the homothallic group, comprising the minority of the species, zygospores are developed from branches of the same thallus or mycelium, and can be obtained from the sowing of a single spore.

4. In the heterothallic group, comprising probably a large majority of the species, zygospores are developed from branches which necessarily belong to thalli or mycelia diverse in character, and can never be obtained from the sowing of a single spore.

5. These sexual strains in an individual species show in general a more or less marked differentiation in vegetative luxuriance, and the more or less luxuriant may be appropriately designated by the use of (+) and (−) signs respectively.

6. In heterothallic species, strains have been found which from their failure to react with (+) and (−) strains of the same form have been called 'neutral,' and a similar neutrality may be induced by cultivation under adverse conditions.

7. In all species of both groups in which the process of conjugation has been carefully followed, the swollen portions (progametes) from which the gametes are cut off do not grow toward each other, as currently believed, but arise from the stimulus of contact between more or less differentiated hyphæ (zygophores), and are from the outset always normally adherent.

8. In some species the zygophores have been demonstrated to be mutually attractive (zygotactic).

9. In the heterogamic subdivision of the homothallic group a distinct and constant differentiation exists between the zygophoric hyphæ and the gametes derived from them, but in the remaining homothallic forms and in all heterothallic forms no such differentiation is apparent.

10. A process of imperfect hybridisation will occur between unlike strains of different heterothallic species in the same or even in different genera, or between a homothallic form and both strains of a heterothallic species.

11. By taking advantage of this character it has been possible to group together in two opposite series the strains of all the heterothallic forms under cultivation.

12. When thus grouped the (−), or less luxuriant strains, will be in one series, while the (+), or more luxuriant, will be in the other.

13. From the foregoing observations it may be concluded:—

(*a*) That the formation of zygospores is a sexual process;
(*b*) That the mycelium of a homothallic species is bisexual;
(*c*) While the mycelium of a heterothallic species is unisexual;
(*d*) And, further, that in the (+) and (−) series of the heterothallic group are represented the two sexes.

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5. *Some General Results on the Localisation of Alkaloids in Plants.* *By* Professor L. Errera.

Microchemistry does not claim in any way to supplant chemistry. Its great value consists in permitting an approach to problems unattainable by ordinary analytical methods, and in accomplishing for physiological (and also for petrographic)

chemistry the work of penetration and localisation which the microscope performs for structure.

For a long time botanical microchemistry has dealt with a limited number of bodies and reactions: cellulose, starch, reducing sugars, inulin, proteid matters, asparagin, tannins, silica, and calcium compounds. Gradually a series of interesting bodies have been added to the original scanty list, such as sulphur, glycogen, salts of iron and other bases, alkaloids, myrosine, certain glycosids, prussic acid, &c.

Although a few valuable preliminary researches had already appeared, a more methodical attempt to localise, in the various tissues, the important group of alkaloids was made in a paper I published in 1887 in collaboration with two of my pupils, Dr. Maistriau and the lamented Dr. Clautriau. We used a great number of general as well as special reagents of the different alkaloids which we examined, for the sake of their mutual control. In consequence of the fact that many alkaloids are closely related to proteids, a great analogy exists in the action of many general reagents on both classes of compounds. This is, of course, a serious difficulty in microchemical determinations. But an alcoholic solution of tartaric acid separates clearly the two groups, dissolving the former from the cells and leaving the latter undissolved, and this method has always given very good results.

Similar lines of investigation have been followed with success within the last eighteen years by a number of my pupils and by many other observers, principally in Holland and Sweden, but also in France, Germany, and Italy.

The more important conclusions arrived at by these researches (which must, of course, be conducted critically) might be summarised as follows:—

(1) The qualitative and to some extent the quantitative distribution of alkaloids (especially those belonging to the pyridic series) can be determined microchemically in the various organs of plants with perfect certainty.

(2) In living cells the alkaloids are eliminated from the protoplasm and gather in the vacuole. It is only in cells which have lost all their liquid contents (as in ripe seeds) or in dead cells that they accumulate in the protoplasm or the cell-wall.

(3) The alkaloids are generally localised:

(*a*) In very active tissues: chiefly in the neighbourhood of growing points (a little behind the initial cells), in the ovules, &c.;

(*b*) In the epidermis, the epidermic hairs, often also in the sub-epidermic layers of vegetative organs, as well as the outer layers of fruits and seeds;

(*c*) Round the fibro-vascular bundles, in certain of their phloem-elements and in the neighbourhood of the pericycle;

(*d*) In the phellogen and the youngest cork-cells (either normal or consecutive to traumatism);

(*e*) In the laticiferous or similar elements, when present.

(4) By means of the microchemical tests many new alkaloid-plants have been discovered, the result being afterwards confirmed by the usual chemical methods, *e.g.* certain Orchidaceæ (where alkaloids were formerly quite unknown), Amaryllidaceæ, Papaveraceæ, Ranunculaceæ, Solanaceæ, &c.

(5) Although the investigation of animal tissues is particularly delicate, observations (yet unpublished) show that even here a microchemical identification of organic bases is sometimes possible—for instance, in *Salamandra*.

(6) Granting that the physiology of alkaloids is far from settled, I think a critical study of their topography as well as their behaviour in germination, growth, etiolation, maturation of seeds, &c., supports the view that they are waste-products, resulting from the catabolism of cytoplasm, and secondarily utilised for defence against animals. A few grams of an alkaloid constitute a protection not less efficient than the strongest spines.

The diminution of the proportion of alkaloids in a given plant is often wrongly interpreted as a proof of their direct consumption as plastic material. But the

decrease may be only apparent—for example, when, the alkaloids remaining unchanged, the amount of other substances becomes greater. Secondly, the fact that a body disappears from the plant does not demonstrate that it has been used as food: it may have been eliminated in a volatile state or otherwise transformed. Thirdly, it must not be forgotten that the percentage of nitrogen in alkaloids is generally very small, so that they would be a very poor nitrogen-store. Even in the case of caffeine, which is exceptionally rich in nitrogen, numerous experiments of Clautriau, confirmed afterwards by Suzuki, lead to the conclusion that it is not a plastic substance. This, nevertheless, does not exclude the possibility of certain products of the splitting-up of the alkaloid molecule being ulteriorly resumed by anabolism, just as the essentially catabolic CO_2 formed in respiration can serve to regenerate starch in the green cell.

6. *The Discovery of a New Alkaloid in Strychnos Nux Vomica.* *By* Dr. J. P. Lotsy.

While experimenting on the physiological significance of the alkaloid in the leaves of cinchona, I found that both brucine and strychnine could be made to disappear, which led me to believe that the leaves were entirely devoid of alkaloid at the end of the experiment. Closer investigation showed, however, that an alkaloid remained, and this alkaloid proved to be a new one, entirely unknown at the time, in strychnos. It was later, at my request, isolated, analysed, and described by Dr. Boorsma.

7. *On the Significance of the so-called Anti-ferment Reaction in Geotropically Stimulated Roots.* *By* Professor F. Czapek.

Up to the present time we have had only one method of deciding whether or no a plant perceives a stimulus of orientation, namely, the method of observing the presence or absence of a reflex reaction. The fact that no reaction occurs may depend either on the stimulus not being perceived, or on the reaction being absent though the stimulus is perceived. In 1897 the author discovered qualitative chemical differences between stimulated and unstimulated root-tips. More recently he has shown that in geotropism (and other tropisms) the oxidation of aromatic amidic acids is checked, especially in the metabolism of tyrosin. This leads to an accumulation of homogentisinic acid, a substance having a well-marked power of reducing silver solutions. This checking action is caused by the formation of an anti-enzyme, which retards the action of the oxydase on the homogentisinic acid. By autolytic experiments which permit the control of the decrease of the reducing power this 'anti-ferment' reaction can easily be established. The reaction in question takes place within 5–6 minutes after the roots have been placed horizontally, and can be applied to the investigation of a number of questions; for instance, the localisation of geotropic sensibility in the root-tip, the behaviour of roots on the klinostat, the relation between geotropic activity and the angle at which the organ is placed. It has been conclusively proved that the anti-ferment reaction is not produced by any general disturbance of normal metabolism, such as is due to poison, mechanical injury, electrical influence, temperature, or light. The anti-ferment reaction only occurs in consequence of perception of stimuli of orientation, and can be used, to the best advantage, to find out whether or no roots or other organs perceive such a stimulus in certain controversial cases.

WEDNESDAY, AUGUST 24.

The following Papers were read:—

1. *A Measurement of the Great Swamp Cypress at Santa Maria del Tule, Mexico.* *By* Alfred P. Maudslay.

2. *Oxidising Enzymes and Katalases in Plants.* *By* Professor R. CHODAT.

3. *On the Pollination of Gymnosperms.* *By* Professor K. FUJII.

4. *The Dissemination and Germination of* Arceuthobium occidentale. *By* Dr. GEORGE J. PEIRCE.

As is well known, the fruits of *Arceuthobium* explode, discharging the 'seed' to a distance often of 25 feet. The conditions for developing the greatest explosive force are (1) an abundance of water in the soil and the host-plant, a species of pine, and (2) moist air. The structure of the fruit is such that it will withstand great internal pressure, and when the fruit finally breaks at the base, the force which stretched the walls of the fruit and compressed the 'seed' is applied against and violently expels the 'seed.' The force develops mainly in consequence of the absorption of water by the gelatinous walls of the cells in certain layers in the fruit.

Germination can take place upon anything, but moist air and moderate warmth are essential. The roots of the seedlings are markedly negatively phototropic. Unless the forward growth of the root be stopped by some obstacle, the root does not attach itself and form a holdfast. Only on rough bark, never on leaves or smooth parts of the bark, is germination followed by attachment and penetration into the host. The haustorium, after penetrating into the cortex, sends out slender branches penetrating the medullary rays and attaching themselves to the tracheids of the host. Meantime buds develop on the mass of parasitic cells in the cortex of the host, and these quickly grow out into branches which at first vegetate and later flower. There is perfect connection between the xylem elements in the bundles of host and parasite. Between the phloem elements of host and parasite parenchymatous cells intervene, as is the case in other green parasites.

5. *On the Transpiration Stream in Small Plants.* *By* Dr. OTTO V. DARBISHIRE.

6. *On a Brilliant Pigment appearing after Injury in Species of* Jacobinia *(N.O. Acanthaceæ).* *By* J. PARKIN, *M.A.*

Shoots of certain species of *Jacobinia*,[1] when bruised and extracted with water, yield a beautiful purplish liquid. Liebmann discovered these species while travelling in Central America about half a century ago, and found the Indians using them for dyeing purposes. Thomas,[2] while in Mexico, submitted the colouring principle of *Jacobinia Mohintli* to a brief examination. Since then these plants seem to have received no further investigation, and their peculiarity is apparently little known to botanists. The object of the present paper is to direct attention to this conspicuous example of pigment-formation, and to give a few details concerning the chromogen and the colouring matter resulting from it. The author hopes to make a full investigation later. So far the observations have been made on the two very similar species, *Jacobinia tinctoria* and *Jacobinia Mohintli*. The peculiar behaviour of the former plant was brought to the writer's notice, when in Ceylon, by Mr. Willis, the Director of the Royal Botanic Gardens, Peradeniya.

The pigment does not exist as such in the living plant, but appears only on death. Leaves, however, killed by boiling water remain green and do not darken.

[1] *Jacobinia tinctoria, J. Mohintli, J. incana, J. neglecta*, and *J. verrucosa*.
[2] *Journ. de Pharm. et de Chimie*, 1866, sér. iv. t. iii. p. 251.

Hence the pigment most likely arises through enzymic action. Slight alkalinity hastens its appearance. Oxygen is also necessary for its formation. It is readily soluble in water and gives a fluorescent solution, purple to violet by transmitted and blood-red by reflected light. A trace of acid robs the solution of most of its colour. The original tint reappears on neutralisation. Alkali turns it bluer, and if strong changes it to green, eventually destroying it. Light does not alter it. All parts of the plant except the flower can produce the pigment.

Such a reducing agent as stannous chloride decolorises an aqueous solution of the pigment. Micro-organisms can also readily bleach it, when oxygen is excluded. On allowing air to enter, the original colour at once returns.

The whole phenomenon bears some resemblance to the way in which indigo arises in plant-tissues. The chromogen of *Jacobinia* is probably a glucoside. In the living cell this substance and its enzyme may be differently situated, perhaps one in the protoplasm and the other in the sap. On the destruction of the cell the two come in contact. The first result is the formation of a colourless body. Then this through the oxygen of the air, possibly assisted by an oxidase, is changed into the pigment.

This behaviour of *Jacobinia* is perhaps only a striking instance of a common feature of plant-juices, viz., their tendency to darken on exposure to the air.

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7. *Saponarin* (*'Soluble Starch'*). *By* George Barger.

Dissolved in the cell-sap of the leaf epidermis of a number of plants there occurs a substance which is coloured blue by a solution of iodine in potassium iodide. This so-called 'soluble starch' was first observed in 1857. Sanio found it in the leaf epidermis of *Gagea lutea,* and Schenk in that of three species of Ornithogalum. Similar observations were afterwards made by Trécul, Nägeli, and Kraus. The last important paper was by the Swiss botanist Dufour, in 1886; he found the substance in about twenty different plants, and investigated its physiological importance. The first (and unpublished) attempt to isolate the substance was made by the late G. Clautriau. Later, when the author was his successor as assistant to Professor L. Errera at the Brussels Botanical Institute, the latter suggested a renewed investigation of the substance.

Fairly large quantities of the chemically pure substance have been isolated from the leaves of *Saponaria officinalis,* L. It has accordingly been called Saponarin; it may or may not be identical with the 'soluble starch' of all the other plants.

Saponarin is a glucoside; it crystallises in small needles, and its probable formula is $C_{21}H_{22}O_{11}$. On hydrolysis it yields glucose and a substance which is closely related to the class of bodies known as flavones.

Flavone derivatives are widely distributed in plants, either as such or combined with sugar, as glucosides. Their physiological function is doubtful; perhaps they are merely waste products.

For the detection of saponarin under the microscope the following reactions can be applied to sections or to strips of the epidermis:—

1. With iodine and potassium iodide the whole of the cell-sap is coloured uniformly blue or violet, and the substance which issues from injured cells produces the same colour outside these cells. On warming, the colour disappears; it reappears on cooling outside the cells.
2. Dilute alkalis and alkaline carbonates, as well as strong hydrochloric or sulphuric acid, produce an intense golden-yellow colour, first inside the cells containing saponarin, and then outside.
3. Ferric chloride produces a reddish-brown colour in these cells; sometimes the colour is green or violet, owing to the simultaneous presence of tannins.

These micro-chemical reactions of saponarin were used in the investigation of its physiological importance, but no very definite results were arrived at.

Dufour's observation was confirmed that the substance does not disappear if the plant is kept in the dark. In etiolated shoots, grown entirely in the dark from a rhizome, the substance is not formed, but it appears when these shoots are transferred to the light, even after they have been cut off from the rhizome and placed in water. Saponarin is therefore produced by the leaves themselves, and only when these are kept in the light.

No enzyme could be found capable of hydrolysing the glucoside, and Professor Beyerinck, of Delft, was kind enough to inform the author that he could not split it with bacteria. From the way in which the substance disappears in Hordeum and Bryonia after the death of the plant, it seems nevertheless likely that an enzyme exists capable of hydrolysing the glucoside.

Nothing is known about the way in which saponarin is useful to the plant. Professor Errera has suggested that as it is only found in the epidermis it might act as a deterrent to animals, after the manner of many alkaloids. The substance is, however, physio'ogically inactive.

Pfeffer has suggested that aromatic substances combine with sugar to form substances which diosmose with difficulty, and so to store up a greater supply of sugar than would be otherwise possible. In this connection it may be observed that saponarin does not truly dissolve in water, but only forms a suspension like starch, so that it does not raise the osmotic pressure of the cell-sap in which it occurs.

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8. *On the Centrosome of the Hepaticæ.* *By* K. Miyeke, *M.A., Ph.D.*

The present communication is a part of my uncompleted study on the spermatogenesis of the Hepaticæ. The study was originally started with the object of repeating the recent remarkable observations of Ikeno on *Merchantia polymorpha*, and was afterwards extended to *Fegatella conica*, *Pellia epiphylla*, *Makinoa crispa*, and a species of *Aneura*.

When the nuclear division is about to take place the nucleus assumes a more or less elliptical shape, and two cytoplasmic radiations or asters are seen at opposite poles of the nucleus. In the centre of the aster no distinct body corresponding to the centrosome was observed. When the spindle is formed the aster entirely disappears, and no structure which might be taken for a centrosome was seen at the spindle pole. I also failed to see, either in the resting stage or in the dividing nucleus of the young antheridium, the structure corresponding to the centrosome of Ikeno.

Only, in the last division in the antheridium of *Merchantia* and *Fegatella* I found a deeply staining body at each pole of the spindle, as figured by Ikeno. Although I have not studied the further behaviour of this body in the development of the spermatozoid, there can be little doubt that it will take part in the formation of cilia as Ikeno described, and may properly be called a blepharoplast. On the other hand, at the spindle pole of the last division of *Makinoa* I was able to recognise neither centrosome nor blepharoplast. However, I often observed two granular bodies, nearly opposite to each other, at some distance from each pole of the spindle. In the spermatid I often observed a deeply staining spherical body in the cytoplasm, which is very probably a blepharoplast.

The identity of these two structures is very probable, although it has not been conclusively proved.

The presence of centrosome in the flowering plants and ferns seems to have been almost conclusively disproved by the careful researches of cytologists during the last ten years. On the other hand, it is still generally believed that in the Bryophytes and Thallophytes centrosome does exist. But my present study seems to show that there is no true centrosome, at least in the Hepaticæ, agreeing with the recent investigation of Gregoire in *Pellia*. The centrosome hitherto reported in the cells of the Hepaticæ is nothing but a centre of cytoplasmic radiations.

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9. *Further Cultural Experiments with 'Biologic Forms' of the* Erysiphaceæ. *By* Ernest S. Salmon, *F.L.S.*

In a recent paper[1] the author described a method of culture by means of which the conidia of 'biologic forms' of *Erysiphe Graminis*, DC., can be induced to infect leaves of host-species which normally are immune to their attacks. In this method of culture the vitality of the inoculated leaf was affected by cutting out a piece of its tissue, or by injuring the leaf by touching it with a red-hot knife.

In the present paper further methods are described by which the same result can be obtained.

A preliminary series of experiments proved that the ascospores of a 'biologic form' are able, in the same manner as the conidia, to infect leaves injured by the removal of a piece of the leaf-tissue, although quite unable to cause any infection of the uninjured leaf of the species used.

An extensive series of experiments was then made in which the leaf previous to inoculation had been injured in one of the following ways: By pricking with a pin, by stamping out a circular piece of the leaf with a cork-borer, by allowing slugs to eat away portions of the leaf, by pressure with weights, or by nipping the leaf with a pair of forceps.

Leaves injured by the action of narcotics and heat were also used, the leaf previous to inoculation being exposed to ether, chloroform, or alcohol vapour, or immersed in a mixture of alcohol and water, or heated gradually in water to 49°·5 or 50° C.

The results of the experiments carried out prove that not only mechanical injuries, such as wounds from cuts, bruises, attacks of slugs, &c., but also injuries due to the action of narcotics and heat, cause a leaf to become susceptible to a 'biologic form' of a fungus to which it is normally immune.

Attention is directed to the fact that these cases of the loss of immunity brought about by causes which affect the vitality of the leaf find their exact parallel in the recorded instances of induced susceptibility in animals to certain diseases caused by bacilli.

To describe cases where a form of a fungus which is specialised to certain host-plants and confined to them under normal circumstances proves able to infect injured parts of a strange host the author proposes the terms *xenoparasite* and *xenoparasitism.* The terms may be used also in the cases where fungi which live usually as saprophytes prove able to infect injured parts of living plants. In the case of the specialised fungus, when on its proper host, the terms *œcoparasite* and *œcoparasitism* are proposed.

A series of experiments was carried out with the object of ascertaining the infection-powers of the conidia of the first generation produced on barley-leaves inoculated—after having been rendered susceptible by the action of ether, or alcohol, or heat—with conidia taken from wheat. In the sixteen cases the conidia produced on such treated barley-leaves proved, when sown simultaneously on normal leaves of barley and wheat, totally unable to cause any infection on the barley, while causing in every case full, and usually virulent, infection on the wheat. In order to see if any subsequent variation would occur in the infection-powers of the conidia of the fungus produced on the treated barley-leaves, conidia of the successive generations produced on wheat, up to the sixteenth generation, were cultivated. In every case the conidia proved able to infect fully leaves of wheat, while never producing any sign of infection on barley.

These experiments demonstrate the fact that the infection-powers of a 'biologic form' are not altered by its residence for one generation on a strange host-plant treated in the manner described, and give also some evidence in favour of the idea of the hereditary nature of the infection-powers of certain 'biologic forms.'

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[1] *Phil. Trans.*, vol. cxcvii. 1904, pp. 107–122.

10. *The Inheritance of Susceptibility and Immunity to the Attacks of Yellow Rust.* By R. H. Biffen, *M.A.*

Evidence was brought forward to show that the liability to certain diseases is inherited, and the results of crossing together races of wheat relatively immune and highly susceptible to the attacks of *Puccinia glumarum* were described in detail. It appears that susceptibility is dominant over immunity in the hybrid, whilst in the second and third generations the immune, or recessive, forms are found in approximately the Mendelian ratio of 1 to 3.

11. *Infection Experiments with various Uredineæ.* By Miss C. M. Gibson.

The following list summarises the results of successful and doubtful cases of the entry of the stomata by the germ tubes of the spores employed :—

Spores	Species of Fungus	from	Host	Result
Uredospores	*Uredo chrysanthemi*	*Chrysanthemum*	*R. ficaria*	Enter freely
Æcidiospores	*Phragmidium rosæ-alpinæ*	*Rosa*	,,	,,
Æcidiospores	*Uromyces Poæ*	*Ranunculus repens*	,,	,,
Æcidiospores	*Æcidium Bunii*	*Bunium flexuosum*	,,	Negative ?
Æcidiospores	*Puccinia Poarum*	*Tussilago farfara*	*Caltha palustris*	Enter freely
Uredospores	*Uromyces geranii*	*Geranium pyrenaicum*	,,	,,
Æcidiospores	*Puccinia Menthæ*	*Mentha*	,,	Enter not very freely
Uredospores	*Puccinia hieracii*	*Carduus ?*	*Caltha*	Enter freely
Æcidiospores	*Phragmidium sanguisorbæ*	*Poterium sanguisorba*	,,	2 or 3 doubtful entries
Uredospores	*Puccinia glumarum*	*Triticum vulgare*	,,	1 certain entry

From the above results it is evident—

1. That the germ tubes from the spores of any uredine may enter almost any plant.
2. That the attractive substance causing entry is not specialised in each species, but is something common to all plants.
3. That the entrance of the stoma by any germ tube cannot be taken as an index of the infective capacity of that germ tube.

The paper also dealt with some experiments on chrysanthemum rust and time experiments on the germinating power of uredo- and æcidio-spores.

12. *On the Normal Histology of the Uredo of* Puccinia glumarum. *By* T. B. P. Evans.

13. *Pineapple Galls of the Spruce.* By E. R. Burdon, *B.A.*

The galls are caused by the hibernating generation of certain aphidæ belonging to the genus *Chermes*.

In the autumn a *Chermes* larva drives its long proboscis into the stem of the

spruce, just below a winter bud or into the bud itself, and thus anchored passes into a hibernating condition. The tip of the proboscis lies in the neighbourhood of the cambium. In the spring the insect awakens, commences to suck, undergoes three ecdyses, and then lays a great number of eggs. It probably injects an irritant into the bud, which is forced into precocious growth, and by the time the bud-scales are thrown off the rudimentary shoot has become enormously swollen and stunted. The swelling proceeds outwards through the cortex into the bases of the young needles, and takes place in such a manner that the spaces in the axils of the needles become converted into chambers. Into the chambers the young larvæ make their way, and there remain until the gall is ripe, when the chambers open and the inhabitants emerge as winged insects, which carry the infection to other trees.

In the early stages the chlorophyll, tannin, resin, resin canals, and secretory cells of every description disappear within the gall area, which consists entirely of enormously swollen parenchymatous cells. After the shoot emerges from the bud-scales and becomes exposed to light these all reappear, though in abnormal situations.

Starch is found in great abundance round the periphery of the gall area, and it is suggested that it may be the ultimate product of the disintegration of the tannin.

The nuclei of the galled cells also become enlarged, and the chromatin network becomes aggregated into numerous wart-like nucleoli. The mitotic figures are of the usual somatic type, and no indication of heterotypical mitoses has yet been found.

The later stages of the gall are still under examination.

The complicated life-cycle of the insect and the connection between it and the well-known larch-blight will be shown by means of a table thrown on to the screen.

The pests may be got rid of by washing both spruces and larches with a paraffin wash during the winter.

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14. *The History and Distribution of Catesby's Pitcher Plant* (Sarracen Catesbæi). *By* Professor JOHN M. MACFARLANE.

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15. *Observations on Two Species of Alpine Rose and their supposed Hybrids.* *By* Professor JOHN M. MACFARLANE.

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16. *Exhibition of a Bigeneric Hybrid between* Gymnadenia *and* Nigritella. *By* Professor JOHN M. MACFARLANE.

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17. *The Destruction of Wooden Paving Blocks by the Fungus* Lentinus lepideus, *Fr.* *By* A. H. REGINALD BULLER, *D.Sc.*, *Ph.D.*

The destruction of a great many paving blocks, made of pine- or fir-wood, in the city of Birmingham is being brought about by *Lentinus lepideus*, a fungus belonging to the Agaricini. Considerable repairs to the pavement are thereby necessitated.

Single blocks, or small groups of blocks, at intervals in the streets go completely rotten, so that one can break up the wood with the fingers. The streets affected become unduly bumpy. In wet weather water collects above places where rotten blocks are.

A number of rotting blocks, obtained from time to time from the streets, were placed in a large damp-chamber. In the course of a few weeks fruit-bodies of *Lentinus lepideus* appeared upon them.

The spores remain unchanged in distilled water and tap-water, but germinate readily in Pasteur's Fluid and in beef-gelatine. They also germinate in decoctions of horse-dung and of pine-wood.

The pavement is probably infected by spores after the blocks have been laid down. The mycelium of the fungus often grows from a rotten block to the neighbouring sound ones. No fruit-bodies are produced in the streets, owing to the traffic.

The wood is rotted by *Lentinus lepideus* in very much the same manner as by the Dry Rot Fungus (*Merulius lacrimans*). It becomes red and is spongy when wet. It shrinks and cracks considerably on drying, and is then very brittle. Cellulose is removed from the cell-walls. Hadromal and a red friable substance are left behind.

The paving blocks, used in the pavements referred to, were dipped in creosote before use. Had they been fully impregnated with that substance, the ravages of *Lentinus lepideus* or any other wood-destroying fungus would have been prevented.

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18. *The Reactions of the Fruit-bodies of* Lentinus lepideus, *Fr., to External Stimuli. By* A. H. REGINALD BULLER, *D.Sc., Ph.D.*

The fruit-bodies of *Lentinus lepideus* were grown upon rotting paving blocks, taken from the streets of Birmingham. The fungus belongs to the Agaricini.

The papillæ, from which the fruit-bodies arise, are not somatotropic, so far as the surface of the wooden substratum is concerned, but grow out perpendicularly to the surface of the mycelial layer on which they develop. Their formation takes place equally well in light or darkness.

Before the development of the pileus, the stipe is perfectly indifferent to geotropic stimuli. In the absence of light it is rectipetal, and in its presence positively heliotropic.

In the absence of light the stipe may continue to grow for weeks or months, and may attain a length of 17 centimetres, but no signs of a pileus make their appearance. The development of the pileus depends on the presence of sufficient illumination. Grown in the dark, therefore, the fruit-bodies are all monstrous and abortive.

While the pileus is developing, the stipe alters its reactions to external stimuli. It becomes negatively geotropic and ceases to be heliotropic.

The pileus is sometimes developed unequally in fruit-bodies with oblique stipes. The longest gills are always formed on the lower side of the stipe. The inequality of development is induced by the stimulus of gravity.

The gills begin their development in such manner as to become perpendicular to the surface of the pileus, from which they are formed. They are never heliotropic, but they become positively geotropic.

Fruit-bodies grown in darkness or weak light are prone to branching, and often become grotesque. Branching may be due to internal causes or to injury of young pilei.

It may be shown that the reactions of the fruit-bodies to external stimuli, as described above, are admirably adapted for the economical distribution of the spores.

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19. *The Structure of the Ascocarp in the Genus* Monascus. *By* B. T. P. BARKER, *M.A.*

Since the publication of the author's earlier paper on this subject Ikeno and Dangeard have published accounts of the structure of the ascocarp of *Monascus purpureus*, and the latter also describes the '*Samsu*' fungus, which he has named

Monascus Barkeri. He agrees with the author that the fructification is not an invested sporangium, but an ascocarp containing numerous small asci, but differs as to the sexual nature of the archicarp, and affirms that a layer of nutritive hyphæ surrounds the asci in the place of the enlarged central cell. Ikeno, on the other hand, disputes the presence of asci, and declares that spore-formation takes place in an enlarged sporangium-like central cell by the massing together and subsequent division of dense portions of its protoplasm.

The author has made a fresh examination of both species, confirms his previous results for *M. Barkeri,* and finds that *M. purpureus* yields corresponding results, the only points of difference being the formation of a basal cell in the ascogonium in many instances and the production of a more vivid red pigment in the case of the latter species. Fusion between the antheridial branch and the ascogonium occurs before the division of the ascogonium, but nuclear fusion at this stage has not been observed with certainty, although pairs of nuclei have been frequently found. The central cell swells considerably, and eventually almost completely encircles the ascogenous hyphæ which originate from it. The cells of the ascogenous hyphæ are often multinucleate, in which case the nuclei are usually paired, but in many instances they are binucleate. The asci appear to be developed from the sub-terminal binucleate cells of branches of these hyphæ, the nuclei fusing and the fusion nucleus then dividing to form eight daughter-nuclei, which become the nuclei of the spores. The spores are formed in the manner described by Harper for other Ascomycetes. By repeated cultivation of *M. purpureus* in beer-wort at 34° C. a variety was isolated which produced conidia only, although normally ascocarps are also formed.

20. *Further Observations on the Ascocarp of* Ryparobius. *By* B. T. P. Barker, *M.A.*

In an earlier paper on this subject it was shown that the archicarp of a species of *Ryparobius* therein described possessed the characters of the archicarp of *Thelebolus,* as described by Brefeld, and differed from those of other species of *Ryparobius,* as figured by Zukal. Recently in some old cultures archicarps were found which, while retaining the typical structure in essentials, varied from the usual type as to the position and the manner of development, and resembled in many respects the type described by Zukal. Further details have also been obtained concerning the cytology of the ascocarp at various stages of its development. Both the antheridial branch and the ascogonium are uninucleate when first formed; but subsequent nuclear division occurs in each organ near the time of fusion. The fusion takes place at the point of contact of these structures, this usually being at or near their apices. Probably a nucleus passes from the former to the latter at this period, and shortly afterwards walls are formed in both, so that the resulting cells are uninucleate, with the exception of the subterminal cell of the ascogonium, which is sometimes found to contain two nuclei close together. Investing hyphæ then develop and encircle the ascogonium, which enlarges considerably and for a short period consists of a row of several uninucleate cells. These are later found in a binucleate, or occasionally a quadrinucleate, condition. From them ascogenous hyphæ arise, and the asci are formed from their binucleate subterminal cells. The two nuclei in these fuse together, and the fusion nucleus enlarges to an enormous extent, keeping pace with the growth of the ascus. The nucleolus now becomes a most striking structure, considerably larger than the vegetative nuclei, and containing apparently almost the whole of the chromatin of the nucleus, so that the nuclear body resembles a large vacuole. Nuclear division then takes place, the nucleolus giving up chromatin and showing very distinct signs of a reticulated structure. The number of chromosomes is probably not less than eight. Successive divisions take place very rapidly, and when sixty-four nuclei are formed they become regularly grouped in dense granular protoplasm around the periphery of the ascus. Other series of divisions now usually occur,

and eventually uninucleate spores are formed, these being ovoid pointed bodies, arranged at the time of their first appearance with their long axes parallel to the radii of the ascus. The protoplasm passes through a series of characteristic changes during the development of the ascus, and the whole process of spore formation seems to be intermediate between the typical methods in sporangia and asci.

21. *Some Features in the Development of the* Geoglossaceæ. *By* Dr. ELIAS J. DURAND.

Section L.—EDUCATIONAL SCIENCE.

President of the Section—The Right Rev. the Lord Bishop of Hereford, D.D., LL.D.

THURSDAY, AUGUST 18.

The President delivered the following Address:—

I am moved to begin this address with a word of personal apology, the strongest feeling in my mind, as I rise to deliver it, being that in the fitness of things some one of the many distinguished representatives of education in this University would have been the natural occupant of this chair on the present occasion; and for my own part I could hardly have brought myself to accept the invitation with which I have been honoured had I not been led to understand that on occasions of this kind it is preferred by the members of the University visited that some one from the outside should be invited as I have been.

Thus I have accepted, not without hesitation and misgiving, but with the more gratitude, as feeling that I am here because of the wish of the Cambridge authorities to have some one connected with the University of Oxford, and I desire that the grateful acknowledgment of this courtesy and kindness should be my first word as President of the Educational Section.

The inclusion of Education among the various sections of this Association for the Advancement of Science is sufficient evidence that a new educational era has begun in this country.

Whatever may be the defects of our educational system or want of system, whatever changes may be necessary to bring it, in the current phrase, up to date, the days of unthinking tradition are over.

Scientific method is entering on its inheritance, and it has begun to include the field of education along with other fields of life and thought within the sphere of its influence.

And scientific minds are asking on every side of us what is the end of true education, and are we on the right way to it?

True education, almost insuperably difficult in practice, has been often defined in words.

Plato told us long ago how it is music for the soul and gymnastic for the body, both intended for the benefit of the soul, how it is a life-long process, how good manners are a branch of it and poetry its principal part, though the poets are but poor educators, how great is the importance of good surroundings, how the young should be reared in wholesome pastures and be late learners of evil, if they must learn it at all, how nothing mean or vile should meet the eye or strike the ear of the young, how in infancy education should be through pleasurable interest, how dangerous it is when ill directed, how it is not so much a process of acquisition as the use of powers already existing in us, not the filling of a vessel, but turning the eye of the soul towards the light, how it aims at ideals and is intended to promote virtue, and is the first and fairest of all things.

In this description, I take it, we most of us agree, though some of Plato's views

would doubtless elicit differences of opinion amongst us, as, for instance, that education ought not to be compulsory, or that it should be the same for women as for men.

One of his statements may be soothing to our English self-complacency, for, as is the habit of idealists in every age, he says that even in Athens they care nothing for educational training, one of the most brilliant of their younger statesmen pleading that it does not matter, because others are as ignorant as he.

Or again, our own Milton sums it up in fewer words, but very impressively, when he says true education fits a man to perform justly, skilfully, and magnanimously all the offices, both private and public, of peace and war.

It is a noble aim which he thus sets before us, to make our sons skilful, just, magnanimous, and every description of aims and methods can be little more than an expansion of it.

Of the importance of right aims and ideals there can, as Plato reminded us, be no question, because of the danger of ill-directed aims, and the lasting nature of early impressions.

What we learnt at school, when all the world was young to us, whether we learnt it with weariness or pain, or under happier influences with a quickening pulse and the glow of enjoyment, passed into the blood, as Stevenson said somewhere, and became native in the memory.

True education, then, as we all acknowledge, aims at cultivating the highest and most efficient type of personality, men not only appropriately and technically equipped for their professional business, but men endowed with the best gifts and inspired with high purposes, men who desire to follow the more excellent ways and to lead others in them, who love knowledge, truth, freedom, justice, in all the relations of life, whether individual or social, men marked by sense of duty and moral thoughtfulness, public spirit, and strength of character.

Such an education is the true basis of individual and national welfare, and experience has abundantly shown how necessary this is to save men from distorted views of history, from wrong conceptions of patriotism and public duty, from mistaken aims and disastrous policy.

Thus, for instance, a good and true education shows us that the true basis of life is moral and economic and not military, and the true aim of both individuals and nations is knowledge, justice, freedom, peace, magnanimity, and not pride, aggression, force, or greed.

Scientific consideration of our subject will of course deal largely with such details as the relative claims of the humanist and the realist, subjects and methods of instruction, the correlation of different grades of education, the adaptation of this or that system to special needs, and so forth; but through all this these fundamental requirements of the true education, as placarded before us by Plato or by Milton, must always hold the chief place, and all others must be kept in due and conscious subordination to these.

This very obvious remark calls for repetition, as we are so apt to lose sight of ideals amidst the dust of controversy about details or methods or practical needs.

How, then, does our English education stand when thus considered? And what signs are there in our life of our having fallen short or fallen behind, or missed the best that was possible in our circumstances?

It may, I venture to think, be fairly said that to a reflective observer, various things are patent which seem to make it expedient that the subject of education should have its place in the proceedings of a scientific association like this, although there may be difference of opinion as to how it should be handled there.

In saying this I have to admit that some educational reformers seem to have doubts as to the propriety of its inclusion in your programme.

The element of personality is so pre-eminently vital in all education that some men say it cannot be treated as wholly scientific in the ordinary sense, and that there is serious risk in subjecting it too rigidly to the methods of investigation which naturally hold the field in the main departments of this Association, and that men who are wholly accustomed to such methods are not the best equipped for dealing with the problems involved in the education of the young.

If I endeavour in a few paragraphs to express what, so far as I understand it, is the ground of this fear in the minds of some thoughtful objectors, I trust I may not be thought to be wasting your time.

This Section is still in its swaddling-clothes. It has to justify its existence in the coming years. It is therefore of moment that it should be started on its course of early growth as free as may be from prejudice and with the sympathy and support of all who, whatever be their views as humanists or realists, as men of letters or men of science, as teachers of religion or men of practical affairs, desire to see the education of the young in our country advancing and expanding on the best lines.

On this account the misgivings or warnings of every thoughtful critic deserve our attention and may be helpful.

In what I am saying it will be understood, I hope, that I am not expressing views of my own, but endeavouring to act as the recording instrument, a very inadequate and old-fashioned instrument, of views which come to me from one quarter and another.

The inclusion of the study of education by the British Association for the Advancement of Science among its subjects of investigation is, they say, not altogether free from risk.

If you treat education too exclusively according to the analytic naturalistic methods of scientific men you incur the danger of unfitting teachers for the best part of their work, which depends on the inspiring influence of personal ideals breathing through all their lessons, on a vivid sense of the subtle element of personality in the pupil, and on their responsible exercise of the power of their own personality.

In giving the scientifically educated teacher the analytic knowledge of the dissecting chamber you may possibly rob him of the magnetic power of personal sympathy and influence. In this sense, at all events, you must not dehumanise him. The most eminent psychologists, the critics tell us, are beginning to recognise the danger, and they bid the educator beware of science which has a great deal to say about mental processes but takes too little account of the emotions and the will, and seems inclined to forget that men are personalities and not plants or trees or machines, and that boys will be boys.

The combination of a living and fruitful experience, these critics assert, with systematic organised scientific methods and processes is more difficult in education than in any other realm of knowledge, because the data are so complicated and so subtle and elusive.

Hence, they say to me quite frankly, the risk of failure to do much that will be of real value in your Educational Section.

In particular I have the impression that they set no great store by presidential addresses, although the address to which you are now listening has at least one merit, that it has no claim to be technically scientific, but is wholly based, so far as any positive conclusions or recommendations are concerned, on practical personal observation and experience.

This section, say the critics, will do its best work by seeking first of all to determine and to set forth:

(1) What field is to be covered when education is to be treated as a scientific study, and what are the limits of the field, taking care to give due regard to right ideals of moral and social progress as a primary part of the whole.

(2) What methods of investigation are appropriate and what are inappropriate to the study of education.

Such are some of the warnings with which we are asked to begin our discussions. The critics ask the men of science to remember that they are leaving their accustomed field of purely natural phenomena, and entering a field of investigation which is largely, if not mainly, social, political, religious, moral, and lends itself only in a limited degree to those problems which men whose sphere is natural science are more accustomed to handle.

These are some of the criticisms which, as men of science, you have to meet, and I may safely leave them to your tender mercies.

For myself my attitude in the whole matter must of necessity be a humble one. For many years of my life I was a teacher, but entirely untrained, or rather self-taught, that is to say, relying for my instruction and guidance entirely on my own reading, observation, experience, and practice.

I belong to the pre-scientific age of Englishmen engaged in education. I grew up to my profession anyhow, like so many others; and now for some years I have ceased even to teach, and so even as an untrained teacher I am out of date.

It is due to this audience and to my subject that I should say thus much. It is my appeal for your kind indulgence.

As regards the critics whose views I have endeavoured to express, I may say at once that I do not go with them, because I am profoundly convinced that our English education needs the influence of more light and more thought from every quarter, and especially from those who are familiar with scientific methods. 'Blessed are they that sow beside all waters.'

Moreover, I hail the application of scientific intelligence and scientific methods to this subject, because, looking back, I am profoundly conscious that I should have done my own educational work far less imperfectly if in my youth I had undergone any rational scientific illuminating preparation for it.

In such a process I should have lost no personal gift or aptitude that I possessed, and I should have gained some early knowledge and confidence and power which would have saved me much discomfort and anxiety and some mistakes and failures, and would have saved my pupils some loss and possibly some distress.

When I turn with these thoughts in my mind and look out over the field of English life I see very strong and valid reasons why our education, its merits, its defects, its methods and results, should be seriously considered here, as also in very different assemblies elsewhere.

Above all, the persistently traditional and unscientific spirit that still pervades so much of it from top to bottom, its lack of reasoned reflection, demands our special attention.

'The want of the idea of science, that is of systematic knowledge,' said Matthew Arnold, 'is, as I have said again and again, the capital want at this moment of English education and English life. Our civil organisation (including our education) still remains what time and chance have made it.'

This was written about thirty-six years ago, and it is, to say the least, a surprising thing that in an age of unusually rapid scientific development it should be, in the main, still so true, as it undoubtedly is, of a great part of our English educational system.

There is the lack of any systematic preparation for the business of teaching which still prevails throughout our middle and upper-class education, although here in Cambridge and in Oxford some excellent pioneer work is being done in the training of teachers.

There is the general lack of interest in education which is still so noticeable in a great deal of English society of all grades, the spirit of indifference to it, and even the tendency to depreciate the intellectual life.

There is the excessive influence of tradition and routine on our great schools and universities, and in some quarters an inert or suspicious conservatism.

There is throughout our middle-class education a state bordering on chaos, a country largely unexplored, a mixture of things good and bad, involving a vast amount of wasted opportunity and undeveloped faculty.

Even in elementary education, which has received the largest share of public attention, there is much that needs to be done in a more thoughtful and scientific spirit.

Party politics have to be eliminated as far as possible, especially ecclesiastical politics.

The fitness of a great deal of the teaching to the special needs and requirements of the children has to be considered afresh.

The tendency to overlook the interests and the attainments of each individual child has to be checked.

The wastefulness of our absurdly truncated system of elementary education stopping abruptly at about twelve years of age and then leaving the children to drift away into an unexplored educational wilderness has to be superseded by some rational system of continuation classes made obligatory. Truly the harvest is a plenteous one for those who desire to uplift our English life by helping forward the best modes of educating the rising generation in a scientific, or, in other words, a wise, intelligent, and large-minded spirit.

Much, it is true, has been done in almost every part of the educational field during the last half-century, but not nearly so much as ardent friends of education anticipated forty years ago.

I have already quoted some significant words from Mr. Arnold's illuminating Report on the Schools and Universities of the Continent as he saw them thirty-seven years ago. If that report had been turned to immediate practical account at the time, if some English statesman, like William von Humboldt, had been enabled with a free hand to take up and give effect to Mr. Arnold's chief suggestions, as Humboldt and his colleagues gave effect to their ideas in Prussia in the years 1808 onwards, the advantage to our country to-day would have been incalculable.

In our insular disregard or depreciation of intellectual and scientific forces actually working in other countries, we have undoubtedly wasted some of that time and tide in human affairs which do not wait for either men or nations.

But, putting regrets aside and turning to some of the practical problems that seem to confront us to-day, I venture to put before you for consideration such cursory and unsystematic observations or suggestions as my personal experience has led me to believe to be of practical importance. For more than this I have no qualification.

In the first place, the growth of crowded city populations and the conditions under which multitudes have for at least two generations been growing up and passing their lives in our great cities have set us face to face with the very serious preliminary problem of physical health.

If our physical manhood decays all else is endangered, so that the first business of the educator is to look well to the conditions of a healthy life from infancy upwards.

Hence the great educational importance of the petition presented by 14,718 medical practitioners, including the heads of the profession, to the central educational authorities of the United Kingdom.

This petition opens with these impressive words:—

'Having constantly before us the serious physical and moral conditions of degeneracy and disease resulting from the neglect and infraction of the elementary laws of hygiene, we venture to urge the Central Educational Authorities of the United Kingdom (the Board of Education of England and Wales, the Scotch Education Department, the Commissioners of National Education in Ireland and the Intermediate Education Board of Ireland) to consider whether it would not be possible to include in the curricula of the Public Elementary Schools, and to encourage in the Secondary Schools, such teaching as may, without developing any tendency to dwell on what is unwholesome, lead all the children to appreciate at their true value healthful bodily conditions as regards cleanliness, pure air, food, drink, &c. In making this request we are well aware that at the present time pupils may receive teaching on the laws of health, by means of subjects almost invariably placed upon the Optional Code. By this method effective instruction is given to a small proportion of the pupils only. This does not appear to us to be adequate. We believe that it should be *compulsory* and be given at a much earlier age than at present.'

And it concludes as follows:—

'In many English-speaking countries, definite attempts are being made to train

the rising generation to appreciate from childhood the nature of those influences which injure physical and mental health. Having regard to the fact that much of the degeneracy, disease, and accident with which medical men are called upon to deal, is directly or indirectly due to the use of alcohol, and that a widespread ignorance prevails concerning not only the nature and properties of this substance but also its effects on the body and the mind, we would urge the Board of Education of England and Wales, the Scotch Education Department and the Irish Education Authorities to include in the simple hygienic teaching which we desire, elementary instruction at an early age on the nature and effects of alcohol. We gladly recognise (1) the value of the teaching on this subject given in some schools in Ireland and in a proportion of the schools of Great Britain, by means of reading primers, moral-instruction talks, &c., and (2) the excellence of the occasional temperance lessons provided in certain schools by voluntary organisations; but until the four Central Educational Authorities of the United Kingdom include this subject as part of the system of National Education, it appears to us that the mass of the pupils must fail as at present to receive that systematic teaching of hygiene and of the nature and effects of alcohol which alone we consider adequate to meet the national need. Finally, we would venture to urge the necessity of ensuring that the training of all teachers shall include adequate instruction in these subjects.'

This petition, coming, as it does, with all the weight of the medical profession, as the expression of their experience and convictions, is, to my mind, one of the most important educational documents which have been published in our time, and it can hardly be disregarded without incurring the charge of folly.

It may be worth while to set it for a moment side by side with the fashionable cult of athleticism, as bringing into relief our curiously unscientific inconsistency in such matters.

On the one hand, in our absent-minded way, we have allowed these generations of town-dwellers, to say nothing of rural villagers, to grow up and live under insanitary conditions which inevitably produce a physically degenerate, enfeebled, and neurotic race of men and women.

On the other hand, in the upper and middle classes, we have been sedulously cultivating the taste for physical exercises, outdoor life, athletics, and sport, thinking nothing of such importance as the development of the body, admiring nothing so much as bodily prowess; carrying all this to such an extent that a natural and wholesome use of athletic exercise has been fostered into a sort of fashionable athleticism, with all its parasitic professionalism, possessing both soul and body.

And the result has been curiously significant; at one end of the scale neglect of the rudiments of sanitation, the loss of the *corpus sanum,* at the other end the idol worship of athleticism, the depreciation of the intellectual life, and the loss of the *mens sana.*

Are we not then in some danger of drifting into the ways of the Greeks, not in their best days but in their decadence, and of the Romans under the demoralising influences of the Empire?

The Greeks, as we are constantly reminded, in the great period of their creative influence, found nothing so absorbing as the things of the mind; a pre-eminent characteristic of their life was their love of knowledge, their fine curiosity, their enjoyment of the things of the imagination and of thought. It has been noted that what specially conciliated an Athenian voter was the gift of a theatre ticket; and this is a very instructive and significant fact when we bear in mind that the theatre was the great teacher of religion, morals, poetry, patriotism, all in one; that it combined the influences of Westminster Abbey, the plays of Shakespeare, and the heroic achievements of the race; whereas to an ordinary English voter these things are too often only as caviare to the general.

If so, our education has before it the task of doing what can be done to alter this; and from the Greeks we may derive both lessons and warnings. It was in the days when this decadence was beginning that their excessive admiration of the professional athlete, what we might call their athletic craze, called forth the bitter jibes of Euripides, and his impressive warnings and exhortations to admire

and to crown with their highest honours, not those who happened to be swiftest of foot or strongest in the wrestling bout, but the man of sound mind, wise and just, who does most to guide others in the more excellent ways, and to uplift the life of his community :

ὅστις ἡγεῖται πόλει
κάλλιστα, σώφρων καὶ δίκαιος ὢν ἀνήρ.

Here we have a warning by no means inappropriate to our own life and its tendencies. It is, indeed, high time to bring serious and, let us say, scientific thought to bear upon the whole matter.

As I look with such thoughts in my mind over those portions of the educational field with which I have been personally familiar, I note various things which seem to call for both consideration and action.

Taking first the elementary school, it is to be noted that our system does too little to draw out and stimulate the faculties or to form the tastes of each individual child.

Classes are still in many cases far too large.

The system of block grants, being inadequately safeguarded or supplemented by inducements to individual children to apply and prepare for certificates of merit or proficiency, however attractive it may be to inspectors and teachers, needs to be very carefully watched in the interests of individual children. The individual child requires the hope and stimulus of some personal recognition or distinction, if its faculties are to be fully roused and its tastes properly cultivated.

Moreover, the aid of scientific thought and experience is needed to bring both the subjects and methods of instruction into closer and more vital relationship with the environment of the children and with their practical requirements, and more weight has to be given to specific ethical teaching, that moral and spiritual training day by day, which has for its end the development and strengthening of character, and taste, and issues in conduct, which is the greater part of life.

And seeing that it is of the essence of any rational or scientific system to avoid needless waste, it is time that our elementary education should no longer be left in its absurdly truncated condition, which allows a child's education to be stopped abruptly and finally at or about the age of twelve, when in the nature of things it should be only beginning. As things are at present, just when the parent of the upper classes is anxiously considering what school will be the best for his son, a vast number of the children of the poorer classes are left by the State to drift out into a wilderness where all things are forgotten.

In this connection, however, it is due to the Board of Education that we take note of the reminders lately issued in the Introduction to the New Code and the memorandum prefixed to the Regulations for the Training of Teachers.

This Introduction to the Code reminds every parent, school-manager, and teacher, very emphatically, that the purpose of the school is to form and strengthen the character and to develop the intelligence of the children, to fit them both practically and intellectually for the work of life, to send them forth with good and healthy tastes and the desire to know, with habits of observation and clear reasoning, with a living interest in great deeds and great men, and some familiarity with, at all events, some portion of the literature and history of their country; and this being so, the special charge and duty of their teachers is by the spirit of their discipline and of their teaching, by their personal example and influence, to foster in the children, as they grow up in their hands, habits of industry, self-control, endurance, perseverance, courage, to teach them reverence for things and persons good or great, to inspire them with love of duty, love of purity, love of justice and of truth, unselfishness, generosity, public spirit, and so not merely to reach their full development as individuals, but also to become upright and useful members of the community in which they live and worthy sons and daughters of the community to which they belong.

Hardly less valuable, as a contribution to education which shall be more thoughtful than hitherto, is the memorandum prefixed to the new Regulations for the Training of Teachers.

I confine myself to one significant quotation from this valuable document:

'Much of the instruction which is given in all subjects must necessarily be founded upon the statements and the experience of other persons; but every education which deserves to be called complete must include some training of the student in those systematic methods of inquiry which are necessary for any assured advance in knowledge, and which are the most truly educative of all mental processes.

'If this scientific spirit is to find its right expression in the teaching given in elementary schools it must be made to imbue the whole study of the intending teacher during his course in the Training College. It must not be confined to any one branch of the curriculum. It is true that, partly as the result of tradition and partly from other reasons, the term "scientific method" has come to be associated more particularly with the study of natural phenomena. But as a matter of fact, scientific method is of equal importance, and is indeed of ancient application, in the fields of history, literature, language, and philosophy; and wherever knowledge of these has made advance, it may be discerned that the essential processes of scientific inquiry have been employed. When Matthew Arnold declared in 1868 that the want of the idea of science, of systematic knowledge, was the capital want of English education and of English life, he was thinking of science as a method and not as a prescribed portion or subject of a curriculum. It cannot be doubted that this want has been seriously prevalent in a large portion of the education and training hitherto provided for elementary school teachers.'

We might, indeed, widen the scope of these observations and say that this want of regard for scientific method has been and is a prevalent want in almost every department and grade of English education.

These unaccustomed utterances from Whitehall may very well prove memorable in the history of English education, as the words of William von Humboldt, quoted by Matthew Arnold, are so memorable in connection with the education of Germany: 'The thing is *not* to let the schools and universities go on in a drowsy and impotent routine; the thing is to raise the culture of the nation ever higher and higher by their means.'

Passing from the sphere of the elementary schools to that of secondary education, we enter on a sphere in which there is much greater need of careful study and the guidance of those who know.

Our secondary education has by the Act of 1902 been handed over very largely to county councils, excellent but heterogeneous bodies, and for the most part not only ignorant of educational needs, methods, and possibilities, but quite unaccustomed to their practical consideration—altogether unprepared and untrained for the responsible work now thrown upon them, and hampered by their besetting fear of the ratepayers.

Add to these difficulties the prejudice, so common in the ordinary English mind, against what is known as the 'expert,' that is, the man who knows from experience, and is therefore likely to be earnest for improvement, and to believe that wise educational expenditure will repay itself, and you see how manifold are the obstacles in the way of immediate progress.

These county authorities need first of all to be themselves instructed and persuaded as to the right subjects for their schools, the co-ordination or proportion of subjects in any scheme to be encouraged, the methods of instruction, the sort of teachers to be appointed, the wisdom of spending public money on good education, as exemplified in other countries, like Germany, Switzerland, the United States, Denmark.

Our local authorities feel and recognise that something is needed, but very often they seem to be like children crying in the dark. From lack of educational knowledge and educational experience they do not always know the difference between the right and the wrong method, or between the good and the bad school.

In our rural districts at all events it may be said further that one of our first needs is to persuade the local authorities by some convincing proof that expendi-

ture on popular education higher than elementary is a wise economy, and that their bread cast on educational waters will come back to them, not after many days, but very soon and in their own homes. Thus my observation has led me to the conclusion that by way of preliminary to progress our new educational authorities need instruction or persuasion as to the importance of a sufficient provision for really good secondary education; and it would greatly expedite progress if the Government could and would offer more liberal secondary education grants to be earned by efficient schools, and initial grants towards buildings and scientific equipment, to be met by contributions from local rates or other local sources, public or private.

Many persons and localities would be ready to tax themselves with the view of securing a Treasury grant not available without such taxation. Meanwhile the wheels of our local educational chariots are tarrying on every side so far as higher education, whether general or technical, is concerned.

It would also stimulate our local educational authorities if they could be more fully informed as to the practical advantages which have been derived from a practical system of popular education in such a country as the United States of America; and still more if they had set plainly before them the wonderful results derived by a poor country like Denmark during the last twenty-five years, and in the face of every disadvantage, from the system of education initiated by Bishop Grundtvig and taken up by the Government.

And the need of our middle classes, especially that of the farmer and tradesmen classes, is very pressing. A great deal of the education they receive is given in schools of which the public know very little, whether as regards qualifications of the staff—moral and intellectual—equipment, or methods of teaching, or even sanitary arrangements; and it is to be feared that much of this education would on inquiry be found to be very poor, if judged by any reasonable standard of modern requirements.

When we pass to the class of schools generally spoken of as public schools, those that look to the ancient Universities as the goal of their best pupils, we enter on another very interesting and important field of study.

But for the beginning of our investigation we have to go behind these schools to the preparatory school, which has now assumed a definite place in secondary education, and therefore calls for serious attention. Some of these schools are very good, so far as the conditions under which they work admit of excellence; in others there is, it is to be feared, much room for improvement.

And such schools are now so largely used by parents that their condition becomes a matter of vital importance, as a boy's progress and prospects, his moral and intellectual future, are very frequently determined for good or ill by his experience in the preparatory school, by the bent which has there been given to his morals, tastes, ambitions, by the fostering of his intellectual gifts or the failure to foster them.

In the course of my own experience I have known many boys whose prospects in life were spoilt by their unhappy beginnings in some preparatory school, and who consequently entered their public school foredoomed to failure.

These schools are in most cases private-adventure schools, conducted for private gain. Their staff consists very often of young men untrained for the work of education, and sometimes underpaid. They are subject to no public inspection or examination; in fact, the general public have no knowledge of their condition.

Seeing how grave are the considerations involved, I hold it to be one of the things needed for the general improvement of our secondary education that every private school, of whatever kind, should be liable to public inspection and public report thereon; that a licence should be required for every such school; and that the staff and their qualifications, and the remuneration given to each of them, the sanitary condition, suitability, and educational equipment of the premises, should all be considered in connection with the giving or withholding of a licence.

As regards the curriculum of the schools preparatory to the public schools, the subjects taught, and the proportion of time allotted to each, it has to be borne in mind that they are not free agents. In this respect they are dependent on the

requirements of the entrance examination at the public schools which they supply; just as those schools in their turn are dependent on the requirements of the university to which they send their pupils.

Thus, when we come to confer with the authorities of the public schools, our first inquiry is whether their entrance examination is such as to conduce to the best system of education from infancy upwards.

Believing, as I do, that there is room for improvement, I would ask them to consider and come to a general agreement as to the subjects on which special stress should be laid. What place, for instance, is occupied in the Eton entrance examination by such subjects as English language and literature, English composition, spelling, handwriting, and reading aloud? What weight is given to elementary drawing, or to an elementary knowledge of natural phenomena, so as to encourage in the preparatory school an interest in the mineral, vegetable, and animal world around us, and to stimulate in early years the habit of observation, and to impress the difference between eyes and no eyes?

Such subjects as these, it is now generally recognised, ought to be given a foremost place and equal weight with the modicum of arithmetic, French, and ancient languages, which have hitherto, as a rule, formed the staple of this entrance examination, and have consequently given an unnatural twist to the earlier education of our boys.

As regards the public schools themselves, if we consider them critically—though, on the other hand, I trust, by no means forgetting their many and great excellencies—the points that invite attention would seem to be such as the following:—

There is undoubtedly a great deal of waste in these schools owing to the poor teaching of untrained masters, who in some cases cannot even maintain reasonable discipline, and in many more have no real knowledge or mastery of the best methods of teaching their subject, be it linguistic, or historical, or literary, or scientific, and have not acquired that first gift of an efficient teacher, the art of interesting their pupils and drawing out their faculties and their tastes.

It would, therefore, be reasonable, as it would certainly be stimulative and advantageous, to require that all masters should be bound to go through some system of well-considered and serious preparation or training for the teacher's work, or at the least a probationary period.

It should, I venture to think, be made a rule that no master could be placed on the *permanent staff* until he was certified and registered as having fully satisfied this requirement and given proof of his efficiency.

And here I would venture to point out to existing masters and mistresses in the leading schools how great a service they may do to the cause of good education if they themselves apply to be registered.

Seeing the advantages which registration is destined to bring to our secondary education by winnowing out inefficient teachers and otherwise, the higher members of the profession may fairly be expected to give their personal adhesion to it as a part of their duty to their profession.

We might almost say to them *noblesse oblige*.

Again, it must, I fear, be admitted that one of the chief defects in our public school education is still to be found in over-attention to memory work, and in the comparative failure to develop powers of thought, taste, and interest in the things of the mind.

And even in the teaching of languages attention has been too exclusively devoted to mere questions of grammar, as if to learn the language were an end in itself, whereas, in the words of Matthew Arnold, 'the true aim of schools and instruction is to develop the powers of our mind and to give us access to vital knowledge.'

For this end, as he reminds us, the philological or grammatical discipline should be more consciously and systematically combined with the matter to which it is ancillary, the end should be kept in view; whereas nine out of ten of our public-school boys seem never to get through the grammatical vestibule at all;

and yet we agree that 'no preliminary discipline should be pressed at the risk of keeping minds from getting at the main matter, a knowledge of themselves and the world.'

This also was written by Mr. Arnold thirty-six years ago, and thoughtful critics are still repeating, and with some reason, that the majority of boys who grow up in our public schools seem hardly to have received an adequate training for many of the higher duties of life.

We hear much more than formerly about the public schools being the best training-place for good citizenship. Therefore, say the critics, it is reasonable to inquire how far their educational system, their ideals, their traditions, their fashions, and the pervading spirit of their life fit the mass of their pupils intellectually and otherwise for the duties of citizenship, and for grappling in the right spirit with the problems that will confront them.

'Any careful observer,' says one of these writers, himself a loyal public-school man, and intimately acquainted with school life, 'any careful observer, who has studied the political moods and opinions of the middle classes in this country during the past few years, can hardly have failed to notice two obviously decisive influences: an ignorance of modern history and a want of imagination. For both of these defects the public schools must bear their full share of blame.

'It may be doubted whether any other nation teaches even its own history so little and so badly.'

The result is that 'to the average public-school and university man the foreign intelligence in his daily paper is of less interest than the county cricket; and though events of far-reaching importance may be happening almost under his eyes he is in the dark as to their significance.'

'As regards the duties and aims of citizenship in all the various affairs of his own country, political, social, economic, he goes out from his school almost wholly uninstructed by the lessons of history, or by any study of the life and the needs of our own times. Again, as it is urged, the lack of imagination is hardly less dangerous to us than lack of instruction in the lessons of history and the social conditions and needs amongst which we have to live and work. No doubt the gift of imagination is a natural gift,—it cannot be created. But, given the thing in the germ, it can be stimulated and developed, or starved, stunted, or even crushed out. No system of education that neglects it is even safe. For, without it, principle becomes bigotry and zeal persecution. It is conscientiousness divorced from imagination that produces Robespierres. Now, it is precisely here that we should expect the public schools to be most helpful, for it is through literature that the faculty is most obviously cultivated, and they all profess to give something of a literary training. But though the intention is excellent the performance is often terribly meagre.' Whatever may be thought of such criticisms as these, which come from within our public-school life, it is, I imagine, generally agreed by those who know both our national needs and the work and influence of our public schools, that there is much room for improvement in regard to methods of teaching, the cultivation of intellectual interests and tastes, and the stimulating habits of thought in the majority of their pupils. In close connection with these considerations there are two questions of practical importance which deserve a prominent place in any study of our public-school education.

The first of these is whether it is good for all boys alike to continue their life at school, especially at a boarding school, up to the age of eighteen or nineteen; and the other is whether more encouragement and pains should not be given to developing the best type of day school, or, to put it somewhat differently, whether the barrack life of the boarding school has not, through fashionable drift and class prejudice, become too predominant a part of our English education at the expense of the home life with all its finer educational influences.

As regards the first of these questions, it will be remembered that Dr. Arnold considered it a matter of vital importance to expedite the growth of a boy from the childish age to that of a man.

In other words, the boy should not be left to grow through the years of critical change from fourteen to nineteen without special regard to his growth in

intellectual taste and moral purpose and thoughtfulness. His education during these critical years should be such as to rouse in him the higher ambitions of a responsible manhood.

Does, then, the actual life of a public school really conduce to this early development in the majority of cases?

My own experience has led me to the conclusion that it cannot be confidently held to do so.

The boys in any of our public schools may be said to fall into two classes—those who in due course reach the sixth form, and during their progress through lower forms have an ambition to reach it; and, on the other hand, a numerous class who do not expect to rise to the sixth, don't care about it, and never exert themselves to reach it.

For the first class, I doubt if any more effective preparation for life has been devised than that of our best English schools; but the case of the second class is somewhat different.

Many of these come to the end of their school time with their intellectual faculties and tastes and their sense of responsibility as men to a great extent undeveloped.

From sixteen to eighteen or nineteen their thoughts, interests, and ambitions have been largely centred in their games and their out-of-school life, with the natural results that their strongest tastes in after life are for amusement and sport.

Some of these boys, after loitering at school to the age of eighteen or nineteen, go to the University as passmen, some begin their preparation for the work of a doctor or a solicitor, and many go straight from school into City life as men of business; and nearly all of them suffer from the lack of intellectual and moral stimulus during these later years of their school life.

Now many of these boys could without difficulty pass the entrance examination to the University at sixteen or seventeen, if well and carefully taught; and I have long held the view that such boys would greatly benefit by going to Oxford or Cambridge at the age of seventeen, or even sixteen, if suitable arrangements could be made.

It was with this conviction in my mind that I published a scheme showing how this experiment might be tried about twenty years ago.

The interval has confirmed me in the opinion that it would be a distinct gain to many boys to take advantage of such a scheme if made available. They would go out into the world from the University at the age of twenty far better equipped and prepared for life, both as regards knowledge and interests, tastes, and character, than by going straight from school at nineteen.

And looking to my own University of Oxford, I see no reason why such younger students should not be safely received.

There are at least three Colleges in that University which would find it easy to adapt their arrangements so as to secure this. Each of these Colleges has a hall in connection with it, well suited for the residence of a college tutor who might have special charge of these younger students, residing in the hall during their first year with somewhat stricter rules as to ordinary discipline and liberty, but in all other respects exactly on a par with the senior undergraduate members of the College.

On the subject of the day school, as compared with the boarding school, a subject which has not hitherto received the attention it deserves, I may venture to repeat here what in substance I have said on other occasions.

Many parents are so situated that they have no choice in the matter; but to the educational inquirer it is a question of much interest and importance.

The boarding school is admitted to excel in turning out strong, self-reliant, sociable, practical men of affairs, men who have learnt by early experience not to think or make too much of small injustices, to rough it, if need be, with equanimity and cheerfulness, and to count it a man's part to endure hardness in a manly spirit. It is a fine type of character which is thus produced, at its best; but the best is not always seen in the result, and the system too often produces an undue deference to public opinion, a spirit of moral compromise, and a loss of

moral enthusiasm. The human soul in its finer parts is a very sensitive thing, and I do not think the barrack life of an average boarding school is always the most favourable for its healthy growth.

As I look back over the school days of my own pupils I feel that those of them had, on the whole, the best education who grew up as day boys in good homes at Clifton College. There they enjoyed all the advantages of the cultivated home, which I need not here enumerate, and at the same time, through the arrangements we made for them, all the best elements in the life of a great boarding school.

In the upper school of 500 boys, we had about 160 day boys living at easy distances from the school.

These boys were divided into two houses—North Town and South Town—about eighty boys in each house, and they were treated for school purposes just as if they were living together in a boarding house.

They were under the same rules as boarders in regard to hours of locking up, or the bounds beyond which they might not go without a note from their parents giving express leave.

Their names were printed in a house list, a master was appointed as their tutor, whose duty it was to look to their educational needs and progress, to their reports and conduct, just as if they had been boarders and he their house master. Each house had its own room or library on the College premises, with books of reference, and so forth, for spare hours, and took its part with the boarding houses, and held its own in all school affairs, games, and other competitions. And my experience of this system compared with others has led me to the conclusion that the form of education which may on the whole claim to be the best is that of a well-organised day school, in which it is clearly understood to be the duty of the masters to give their life to the boys in school and out of school, just as if they were at a boarding school, and in which the boys are distributed into houses for school purposes, just as if they were living in a boarding house. Under such a system they get the best of both worlds, home and school.

From the public school we pass naturally to the Universities, and the first question that meets us is the influence they exercise on school education, through their requirements on admission or matriculation and the bestowal of their endowments and other prizes.

On this part of my subject I have seen no reason to alter or modify what I said at Glasgow three years ago, and therefore I merely enumerate and emphasise the suggestions which I put forward on that occasion for the improvement of education both at school and college.

I hold that it would be equivalent to pouring a new stream of intellectual influence through our secondary education if Oxford and Cambridge were to agree on some such requirements as the following:—

1. In the matriculation examination (*a*) candidates to be free to offer some adequate equivalent in place of Greek.

(*b*) An elementary knowledge of some branch of natural science, and of one modern language to be required of all candidates.

(*c*) A knowledge of some period of English history and literature also to be required of every candidate, and ability to write English to be tested.

(*d*) The examination in Latin and any other foreign language to include questions on the subject-matter of any prepared books offered, some questions on history and literature, and translation of easy passages not previously prepared.

(*e*) Marks of distinction should be given for work of superior merit in any branch of this examination, as, indeed, of every pass examination conducted by the University.

Candidates should not be excluded from residence before passing this examination, nor should they be required to pass in all subjects at the same time; but the completion of this examination would be the necessary preliminary to entry for any other examination required for a degree.

2. On the question of endowments and the minimising of waste in the adminis-

tration of them there is much to be said, and I would suggest for consideration:

(1) That, as a rule, open scholarships and exhibitions might be reduced to free tuition, free rooms, and free dinners in hall, or thereabouts.

(2) That every holder of an open scholarship or exhibition, whose circumstances were such that he needed augmentation, should, on application, receive such augmentation as the College authorities considered sufficient.

(3) That care should be taken to discourage premature specialisation at school.

For this end it should be required that no scholar should enjoy the emoluments of his scholarship until he had passed the matriculation examination described above; and a fair proportion of scholarships should be awarded for excellence in a combination of subjects.

The Universities might also do good service in the way of stimulating secondary education, if some small proportion of their entrance scholarships were distributed over the country as county scholarships, on condition that the county contributed an equal amount in every case.

In this way some equivalent for the endowments, so cynically confiscated by the Education Act of 1902, might be recovered and used for the benefit of poor and meritorious students.

Other reforms, which would, as I believe, be productive of valuable results, are the requiring from every candidate for a degree a knowledge of some portion of our own literature and history, and the encouragement of intellectual interests and ambitions by abolishing all purely pass examinations. A pass examination, in which the candidates are invited simply to aim at a minimum of knowledge or attainment, is hardly worthy of a university. The opportunity of winning some mark of distinction in this or that portion of what is now a pass examination would frequently rouse some latent ambition in an idle man, and transform the whole spirit of his work.

Thus a modest reform of this kind might be of great practical benefit to the nation by helping in its degree to intellectualise the life of a great many of our young men, and draw out unsuspected interests, faculties, and tastes.

My observations have run to such a length that I must, perforce, conclude, leaving untouched other aspects of University education and training, whether in the old or the new universities, as also the whole subject of the higher education of women, and its proper relationship to traditional systems of instruction and study, framed and intended for men.

And my last word is a word of practical inquiry. How is this Section to be made of most value as an instrument of educational progress?

I leave the answer to this question to those more competent to give it, merely putting on record my own feeling that it may do a valuable service and supply one of our special educational needs, if the working committee of the Section, enlarged by the addition of various representative persons, makes it a duty to collect and publish year by year in succession a series of papers, the best that can be written by recognised authorities, on the chief branches of our English education, dwelling on its immediate and pressing needs, and how best to supply them. To do this the Committee should set to work systematically, commencing in October with monthly meetings, and formulating, without delay, the scheme or series of papers to be prepared and presented to the next meeting of the Association.

The following Papers were read:—

1. *The Present Educational Position of Logic and Psychology.*
By Miss E. E. C. Jones.

There are several reasons for paying special attention at present to the teaching of logic and psychology:

(*a*) Some knowledge of these subjects is part of the qualification for getting on to the new Teachers' Register.

(*b*) Secondary teachers are now called upon to undergo training, and some logic and psychology are required for the teachers' training examinations.

(*c*) There is a widespread movement towards bringing the standard of religious knowledge up to the level ordinarily required in other departments.

(*d*) There are signs of a widening interest in philosophical questions.

It is very necessary that those who take up logic and psychology as a stepping-stone to the profession of teaching should give to those subjects serious and well-directed study, and should have genuine interest in them and some grasp of their scope and meaning. It is likewise desirable that students of religious doctrine, or of the great questions of philosophy, should bring to their study an equipment of logical method and psychological knowledge. At the same time, it will not be disputed that at present these requirements are not, and perhaps hardly can be, adequately met.

My aim here is briefly to draw attention to this state of things—to the facts that, on the one hand, from various causes, logical and psychological studies hold a position of great and growing importance in English thought and education, while, on the other hand, to some extent at least, the quality, quantity, and organisation of the instruction supplied leaves much to be desired; and to point out that, consequently, the practical treatment of these subjects calls for special recognition and careful attention from educationists.

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2. *Comparison of the Intellectual Power of the Two Sexes.* *By* Dr. J. de Körösy.

The material of the following statistics is drawn from observations made during the last twenty-seven years in the schools of Buda Pest, where, since 1873, a special report on the progress of each pupil has to be sent to the author's office. These individual reports (amounting latterly to 60,000 per annum) represent together 808,350 cases; they relate at first to the elementary schools (ages six to twelve years) only; later they include the higher elementary schools ('citizen schools,' ten to sixteen years), and in the last years the grammar schools also.

(1) *General Progress in the Elementary Schools; twenty-seven years' Observations.*

The test applied is the number of children who have to repeat their year's work instead of passing on to the next standard. Of 412,758 boys and 350,382 girls, 69,422 boys (16·8 per cent.) and 54,391 girls (15·8 per cent.) repeated their work. These figures show a slight superiority on the part of the girls. If we observe the divergence standard by standard, we see that the boys and girls are nearly level at first, but that the advantage of the latter increases with age.

Standard	Percentage repeating the Year's Work		Number of Girls to 100 Boys
	Boys	Girls	
I.	22·5	22·2	99
II.	16·6	15·4	93
III.	16·3	13·8	84
IV.	12·2	9·2	75
V.	9·8	5·6	57
VI.	4·7	2·7	58

(2) *Special Progress in the Fourth Standard of the Elementary Schools* (172,477 *cases*).

The frequency of the best marks ('very good' and 'good') was—

	Boys	Girls
In Mother-tongue . .	23·6 per cent.	32·3 per cent.
In Arithmetic . .	28·0 „	37·3 „
In Geography . .	29·2 „	36·9 „

(3) *Progress in the Higher Elementary Schools.*

(*a*) Of 14,201 boys and 20,588 girls, 840 boys (6·2 per cent.) and 450 girls (2·2 per cent.) had to repeat their work.

(*b*) By standards:—

Standard	Percentage repeating their Year's Work		Number of Girls to 100 Boys
	Boys	Girls	
I.	11·0	3·1	28
II.	4·8	2·7	57
III.	4·6	1·8	35
IV.	3·0	0·6	20
Average . .	6·2	2·2	35

(*c*) Frequency of the best marks in the Fourth Standard:—

	Boys	Girls
In Mother-tongue . .	16·7 per cent.	44·6 per cent.
„ German	12·2 „	39·2 „
„ History	20·9 „	47·3 „
„ Arithmetic	10·8 „	35·3 „

The superiority of girls is really puzzling here, especially in arithmetic.

In this division, however, there are difficulties, for the female group is more selected than the male; for the boys who follow the higher elementary classes, instead of entering secondary schools, are from a class less gifted than the ordinary, while the contrary is the case with the girls. This disturbing cause exercises greater influence in the grammar school, as only the most talented and most ambitious girls enter the Latin schools. Besides this the system of teaching and examination is more favourable to the girls.[1] Thus the elementary schools furnish the most reliable measure, especially where their attendance is, as in Hungary, compulsory.

Conclusion.

The results are all in favour of the female sex, but relate only to children. Since not only in sciences, but also in poetry and (with exception of the stage) in arts, the great work of human progress has been accomplished by the male sex, one is obliged to suppose that with the age of ripening the feminine intellect develops itself more slowly than the masculine.

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3. *The Teaching of Experimental Science in the Secondary Schools of Ireland. By the* Right Rev. Gerald Molloy, *D.D., D.Sc.*

The education given in the secondary schools of Ireland is controlled and guided, in large measure, by a body of Commissioners known as the Intermediate Education Board. This Board was constituted by Act of Parliament in 1878, and administers a fund of about 90,000*l.* a year. For many years this fund was distributed on the results of examination alone; and the programme of the Board was not favourable to the study of experimental science in the schools. But in the year 1900 the Board was empowered, under a new Act, to supplement examination by inspection, and, in the distribution of grants, takes account of the results of inspection as well as the results of examination.

[1] At the examination, which takes place at the end of the grammar school course, there were rejected (1900–03) 494 young men—22·4 per cent.
22 girls —10·3 „

This change led to an important reform, in which the Board has been greatly aided by the co-operation of the Department of Agriculture and Technical Instruction. To this Department was transferred, in 1901, the administration of the Parliamentary vote for science and art in Ireland, which had been previously administered from South Kensington. As the Intermediate Board and the Department were dealing with practically the same schools, it was agreed to adopt a common programme in science subjects, and to carry out a common system of examination and inspection.

The programme adopted under this arrangement, which includes two years of a preliminary course and two years more of advanced teaching in various special subjects, is fully set out in the paper. It involved, in effect, an entirely new departure in the teaching of experimental science in Ireland; substituting, to a large extent, practical work in the laboratory for the study of books, and testing the efficiency of schools by actual inspection of the work done, as well as by written papers.

One of the chief difficulties encountered in the introduction of this new system was to provide a supply of competent teachers. This task was taken up by the Department, as the training of teachers does not fall within the functions of the Intermediate Board. The plan adopted was twofold. First, summer classes for teachers were held at various centres; and teachers who attend these classes, and afterwards satisfy the examiners, obtain provisional certificates to teach the course in which they have been so trained. This is only a temporary expedient, intended to meet the urgent need of the moment.

But as the permanent element in their scheme the Department propose to grant the 'Irish Teacher's Science Certificate' to all students who pass through a three years' course, prescribed for the purpose, in the Royal College of Science, Dublin. They will also recognise as qualified teachers students who have followed a similar course in any university or technical college, and who have obtained the corresponding degree or diploma.

The next difficulty was the want of laboratories and laboratory equipment. This difficulty has been met by the cordial and very remarkable co-operation of the schools and the local authorities with the efforts made by the Department and the Intermediate Education Board. The Department designed plans to suit the circumstances of each particular school, and prescribed the necessary apparatus to be provided. Then loans were advanced by the Intermediate Board, and grants were made by the Department to help the schools to meet the cost of building and equipment. The county and borough councils also lent their aid in many cases, by allocating to the same purpose a portion of the funds placed at their disposal for technical education. The result has been that 214 schools are now provided with all that is needed for the two years' instruction of the preliminary course; and many of these are further provided with the equipment prescribed for one or more years of the special courses.

The new system now embraces all the secondary schools of the country, about 250 in number, with a school population of about 20,000 pupils. Of these 20,000 pupils, somewhat more than 9,000 were under instruction in the preliminary course during the school year 1903–4, and about 1,500 in one or more of the special subjects. This represents a very satisfactory progress, in what is practically a new line of study, within the short period of four years.

It is encouraging to hear that the subject of experimental science, taught on the new lines, is popular both with teachers and pupils. I am informed that a large number of pupils have developed quite a remarkable taste for laboratory work, and that many who had been regarded as dull and inert in other studies, have shown themselves alert and bright in this new field of nature knowledge that has been opened to them.

FRIDAY, AUGUST 19.

The following Papers and Report were read :—

1. *Specialisation in Science Teaching in Secondary Schools.* *By* J. H. LEONARD, *B.Sc.*

While it is admitted that too early a specialisation is an evil, indications are not wanting which show that the efficiency of science teaching in schools is itself threatened with a particular kind of specialism.

A sketch was given of the broad lines which school science teaching may be supposed to follow, emphasis being laid upon its practical nature and the mental training involved.

In contrast to this, certain cases were cited where mechanics is studied in some detail before any attention is paid to such branches of physics as optics, electricity, and magnetism. In other cases, again, experiments in titration are performed before sufficient progress has been made in elementary chemistry.

Botany and physiography meet with no recognition in such schools.

It was maintained that such instances as these exemplify what may be termed 'specialisation' for want of a better word, *i.e.*, one study is accorded undue prominence.

It was shown that the effects of such 'specialism' are bad, since the school time is not proportionately allotted—*e.g.*, the omission of botany—while the effect on the scholars themselves, so far as can be judged, is to weary them instead of maintaining their interest.

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2. *Short Description of 'Realistic Arithmetic.'* *By* Lieut.-Colonel G. MACKINLAY, *late R.A.*

This apparatus consists of a series of blocks of different sizes, each approximately of the proportions of an ordinary brick, threaded on cords for convenience of manipulation.

The exact proportions of each block are such that ten of one size placed together exactly make the figure of one of the next larger blocks, and all the blocks are similar figures. No other proportions except those adopted in 'Realistic Arithmetic' (in which the lengths of edges always increase by the factor $\sqrt[3]{10}$, which is approximately 2·1544) will fulfil these conditions. Evidently a cube will not do so, as ten cubes will not build up into one larger one.

This harmonious arrangement leads to a very simple and real demonstration of 'carrying' in addition and 'decomposing,' or 'borrowing,' in subtraction. Sums in addition, subtraction, multiplication, division, &c., can be actually carried out with magnitudes which are *really* what they profess to be.

Considerable magnitudes can be faithfully represented; for instance, one of the smallest blocks is really one-millionth part of a large block.

Decimals follow in the most natural manner, and all difficulties can be cleared away; for instance, it can be shown at once that a long string of decimals is less than 1.

Fractions and proportion can also be illustrated by means of 'Realistic Arithmetic.' Though chiefly intended for the use of little children, older ones may refer to it occasionally, as such things as 'scales of notation,' 'limits,' and even an illustration of the differential calculus, can be given by its aid.

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3. *Report on the Influence of Examinations.*—See Reports, p. 360.

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4. *Discussion on School-leaving Certificates.* *Opened by the* Rev. Canon G. C. Bell, *M.A.*

The multiplicity of preliminary examinations either held by the various professional councils, or recognised by them as guaranteeing a sufficiently high standard of general education to enable candidates to begin professional training, led to a conference of all parties concerned, and ultimately to the proposals of the Board of Education. The want of uniformity in curricula and in details of individual subjects demanded by the various examining bodies causes the greatest possible disorganisation in a class or form in which, perhaps, several pupils are being prepared for different examinations of similar general standard, but varying greatly in detail.

English schools have gradually become entangled in the coils of an incredibly complex system of examinations; such bodies as the Oxford and Cambridge Joint University Board and the Local Examinations Board have endeavoured to adapt their examinations to the needs and convenience of the schools, but have not completely remedied the disadvantages of the present system, in that they have not succeeded in getting into touch and sympathy with the teachers and their pupils.

Uniform regulations for different types of schools tend to mould unwisely the curricula and methods of teaching. The new proposals aim at combining freedom with a scientific co-ordination of various types and stages of education.

Government aid was, until 1902, given exclusively to 'schools of science,' but since that date grants have been given to 'Division B' schools, in which much less time is devoted to scientific subjects.

The Consultative Committee recognises that it would be an evil for the State to become solely responsible for examinations of school-leaving type, and recommends that considerable freedom should be allowed to schools in choosing their examinations, which, however, in every case are to be subject to the influence of the University and the teaching staff of the school.

Effective means of co-ordinating the examination with the teaching are provided by the following proposals:—

(1) Schools presenting pupils for certificates will previously be inspected, and reported upon to the examining body, which can then adapt its examination to the special aims and character of the school.

(2) The examination will be conjointly conducted by representatives of the examining body and of the teaching staff.

The proposals are issued tentatively, in order to obtain by the end of the present year an expression of opinion as to their feasibility; it is hoped that such opinion will not be so negative as to induce the Board of Education to abstain from action.

Sir A. Rücker said that the subject was rather inconvenient for discussion, because the Board of Education had only just submitted the proposals of the Consultative Committee to the authorities concerned, and their views had not yet been pronounced. He must speak for himself, and not for the University of London, which for two years had been carrying out a scheme similar to that now propounded by the Consultative Committee. There could be no doubt as to the immense importance of the proposed reform in its general character. The multiplication of examinations of the same standard was indefensible. The University had abandoned the name of school-leaving examinations, because it made the parent suppose that the examination implied the desirability of the child leaving school at once. There was every desire to keep in close working contact with the schools, and though in the ordinary Matriculation Examination it was impossible to carry out a practical examination, such a feature was now introduced into school examinations for matriculation. His main feeling in regard to the scheme of the Board of Education was one of great disappointment, because the Consultative Committee had not really faced the difficulties of the situation. It was easy to draw up a scheme which would work well if we were starting *ab initio.*

But the situation was complicated by the fact that the Universities of Oxford, Cambridge, and London stood on a separate footing, in that for many years they had held what were at least the nearest possible approach to school-leaving examinations. Frankly, it was necessary to consider the finances of the whole position, and this point the Consultative Committee had put completely on one side. The University of London, for instance, had been started on its new career with the magnificent endowment of 8,000*l.* a year, and it could not be forgotten that, even when only a reasonable fee was charged, examination carried out on a large scale was a profitable thing for the examining body. But it must not be supposed that he was not absolutely in favour of some such scheme as that propounded by the Consultative Committee.

Mr. Gray, M.P., said that no educational proposal more far-reaching than this of the Consultative Committee of the Board of Education had been made for many years. It would revolutionise the secondary schools of the country, and was equivalent to a large addition to the length of the school life of the children. The Consultative Committee was bound to have regard to the interests of the children rather than to the fees of any university. If the examination of the university were adapted to the curriculum of the school examined, and if the teaching staff of the school were allowed to play a large part in the examination, the influence of the reform was sure to be beneficial. It was especially necessary to define the sort of examination to be insisted on in view of the fact that the new local education authorities, who were to have charge of secondary education, would certainly insist on some examination test as a qualification for their grant.

The Rev. R. D. Swallow noticed that the scheme did not seem to recognise the two classes of secondary schools which were coming into existence. Side by side with the older endowed schools there were springing up everywhere new secondary schools which were only revived Cockerton schools, and the scheme was inappropriate for these. He said that though the Headmasters' Association had not had time to consider the proposals of the Consultative Committee, he could assert that it was strongly opposed to the examinations for leaving certificates being left in the hands of a central board, but it deprecated no less strongly the idea, which was gaining ground, of attaching schools to special universities, which would be a first step to the denationalisation of Oxford and Cambridge.

Dr. Mangold agreed to the general principles laid down in the paper which had been read. He emphasised the importance of examining the whole career of candidates, and not depending on one performance only. Germany is satisfied with this feature of her leaving examinations, and he had no doubt that the system would prove a success in this country.

Principal Griffiths said that the danger of a central board was that it became too much involved in routine and red-tape. He hoped that the central board proposed by the Consultative Committee would be a purely advisory and inspecting body, and not one charged with executive responsibility. At present the new education authorities regarded the teachers with some distrust. They would not readily allow the teachers to take their proper place in the conduct of examinations, but gave a heart-breaking attention to the exact number of marks earned by candidates. Any new scheme should be directed to subordinating the effect of direct examination marks and increasing the importance of teachers' reports. The chief business of educationists at present was to educate the new local education authorities.

Sir Oliver Lodge said that the departure heralded in the Report of the Consultative Committee was allied to one which the Birmingham University intended to put in practice. They proposed there to hold school examinations in which the teachers should be asked to co-operate, and in which the certificates should be awarded in consultation with the teachers. In time all the universities would no doubt recognise each other's results, for at present the multiplicity of examinations was intolerable, and the preparation for purely external examination was not good for methods of teaching. The business of the university or educational centre of the district was simply to unify the standard of examination as much as possible. The school teacher might be left to determine the relative

value of his pupils, and then the absolute value could be determined by the outside authority. He was sure that the country was ready for some such experiment as that proposed, and no mere vested interests ought to be allowed to stand in the way.

Dr. R. D. Roberts: The scheme of the Consultative Committee sets out an ideal and embodies two essential principles. First, that the tyranny exercised by the multiplicity of entrance examinations to the universities and various professions must be broken; and, second, that the teacher should have a share in conducting the examinations. The serious difficulty in the way of imposing a new system of examinations is that the three great Universities of Oxford, Cambridge, and London have all established systems of examination, which have been to some extent doing the work—viz., the Joint-Board Examination, the Local Examinations of Oxford and Cambridge, and the Matriculation Examination and School-Leaving Certificate system of London. It seemed to him that the solution of the difficulty would be found in the voluntary co-operation of the universities. Negotiations are going on between the three universities named with the view of seeing whether a plan might not be devised for the mutual recognition of each other's certificates. A joint committee had reported favourably, and had recommended a plan which had been approved by the Senate of the University of London and by the Council of the Senate of the University of Cambridge. The matter was still under the consideration of the Hebdomadal Council of the University of Oxford. If the plan were approved by the Universities of Oxford and Cambridge, the beginnings of a practical scheme for carrying out the principles of the Consultative Committee's Report would have been laid down. The University of London has already for nearly two years been carrying on a school-leaving certificate system on the lines of the Consultative Committee's Report, and he believed it was by experiments of that kind, carried on by different universities, that the difficult problems could be most successfully attacked.

Mr. Fordham said that the new local education authorities were most anxious to work in touch with every part of the great mechanism of education, and they regarded the teachers as the basis of that system. He did not think they were (as had been suggested) suspicious of the teaching staff. He thought the universities, while retaining their national, and even international, position and importance, should take a large share in the new local educational work. They could help to standardise education in all its grades; and he thought the University of Cambridge might act in this way for East Anglia. Possibly the new authorities would not be for long satisfied with the present system of inspection by officers of the Board of Education, but would be inclined to set up standards of educational progress of their own, in all stages of education. In such a work the universities could take a large and valuable part. He hoped they would not hold aloof from the general progress of education, but would associate themselves cordially with the new authorities and their efforts.

Miss A. J. Cooper said that the consideration urged by Sir Arthur Rücker was much more than a question of the vested interest of universities. It was the question of utilising the great body of experience gained in the field of examination through a long course of years. What was wanted really was some system which would make examinations various, but of corresponding standard, and if at the start all the work done by existing examining bodies were ignored, that equating standard might be missed. It was desirable to keep in the examination system the best elements of our present secondary schools, and also to make more use of teachers in examination work than had hitherto been done.

Mr. Oscar Browning said that neither the examinations of the Joint Board nor the Local Examinations could be regarded as an adequate substitute for the examination which was now proposed in the Report of the Consultative Committee.

The Rev. T. C. Fitzpatrick, speaking as one closely concerned with the work of the University Joint Board, said that that Board had shown itself not only responsive to a great need, but fully alive to the deficiencies of the old system and to the demands of the new. They now held a school-leaving examination in which the character of the education given in the school was duly recognised.

Mr. Cloudesley Brereton hoped that the local authorities would not establish examination boards of their own, or the examination evil would be increased tenfold.

Mr. W. L. Mollison regretted that the proposed scheme indicated an intention to consider Oxford and Cambridge as local or district Universities instead of national institutions. Considering how universally examinations were condemned as destructive of true education, he regarded it as amazing that a new scheme of examination should be put forward as a panacea for our educational woes. The Moseley Commission on American education showed how the Commissioners regarded the absence of examinations as among the best features of American education and one to be imitated in England. Further, he urged that a central board, as advocated by the Advisory Committee, would become infinitely more rigid than any of the existing examining bodies. The true solution was modifications by the Universities themselves and arrangements for the interchange of their first public examinations. Negotiations for this purpose were now going on between Oxford, Cambridge, and London.

The Rev. Dr. Gray said that he would not have intervened in the debate had not a reference been made to the Moseley Commission, of which he happened to have been a member. Mr. Mollison had said that American education was characterised by a freedom from examinations, a freedom unknown to English educationists. This was an unmixed blessing, and had had a beneficial effect on education in America. We in England wanted some stimulus, apart from examinations, to make our children love work for its own sake. He, however, believed that we were starting a new educational era in this respect.

The Bishop of Hereford said it was obvious that there must be a period of transition before the new system could be introduced, and he hoped that continuity would not be broken. The financial side of the question could not be altogether neglected, but he was of opinion that we can evolve a new system, and that the financial difficulty could be easily settled. In conclusion, he would read a summary of the discussion which had been drawn up by Sir Oliver Lodge:—'If the universities thought fit each to inaugurate a scheme whereby, in addition to existing examinations, which for the present can be taken as options, schools may submit themselves for specific inspection and examination on the general lines of the Report of the Consultative Committee and the Board of Education; the result being that scholars above a certain grade shall receive a certificate specifying the range of subjects on its face, a certificate which shall be taken into account, and, if satisfactory, admitted as excusing the holder from the whole or any part of a general entrance test for any university or professional body; the members of this Section would welcome such a procedure and consider it educationally desirable.'

5. *The Need of Scientific Method in Elementary Rural Instruction.* *By* A. D. Hall, *M.A.*

The author said that for some years now there had been a widespread effort to introduce into our rural elementary schools some form of instruction which should be based on things rather than on books, and which should be in touch with the activities of country life. It was of far more importance that the intelligence of the country child should be educated than that of the town child, who, as a clerk or artisan, had in after-life to carry out some small detail of a great organisation with care and despatch. But the country child would need to be an individual, as even the care of stock or the growing of cabbages could not be done purely by rote. The prime condition in the form of instruction needed was that it should be based on experiment, so that parent and child might both realise that school had something to do with life and was not a wholly useless convention. The particular subject of instruction was of less moment than the method, which should teach observation and the reasoning from observation. The experiment in every case ought to be done, and not merely described on the

blackboard, and in this matter the current generation of teachers were not honest. A detached series of lessons was to be avoided. One lesson ought to grow out of the other, and things learnt in previous lessons should be necessary to the proper interpretation of the later work. Incidentally the work should draw in all the other school subjects; composition, for instance, should be concerned with the description of experiments already performed. As to the subjects of study, nothing lent itself better to school treatment than the life of a plant. No doubt the difficulties of training colleges were great; but, unfortunately, it was those institutions which had least learnt the lesson of working on the scientific method. They regarded their function as that of providing information instead of enlightenment. The time now given to getting up books about Herbert and Froebel might be better devoted to practising what those theorists were dimly feeling after—education from the thing, and not from words, experiment as a means of observation and research. The 'nature study' which prevailed so largely in our schools to-day had too often no more relation to the study of nature than art muslins had to art. Nature study should not consist of little lessons picked up here and there—the interesting sugar-plums of science—of a lesson on seed dispersal, followed by one on tadpoles. There must be system and an avoidance of the formal science of the text-books. Above all, there must be no attempt to make the teaching complete. From the lowest to the highest forms of teaching gaps must be left for the student to fill up on his own account.

MONDAY, AUGUST 22.

1. *Discussion on the Training of Teachers and the Local Education Authorities. Opened by the* Right Hon. HENRY HOBHOUSE, *M.P.*

Probably the most important factor in our educational progress at the present moment is the training of our teachers. This has been recognised as a matter of national concern, not only by a formal resolution passed last March by the House of Commons, but by training being insisted upon as a condition of registration under the recent regulations. But the actual establishment of training colleges has *more nostro* long been left to private initiative, and the deficiencies which have naturally resulted are now under the Act of 1902 to be supplied by the action of the local authorities and not of the State. The object of the present paper is briefly to indicate the difficulties which beset local bodies in their endeavours to perform what is really a national task.

It must first be noted that (taking county councils and county borough councils only) there are some 130 local authorities for higher education in England and Wales. Some of these dispose of very small funds, considering the numerous and important objects of their expenditure, which include secondary and evening schools, scholarships, and technical classes of all kinds. In default of pressure from the central authority some of these local bodies will be slow to raise more money for the training of teachers. The Government, it will be said, offer liberal contributions, amounting, in the case of the larger training colleges, almost to the whole cost of maintenance. But it is the initial cost of establishing new institutions with expensive buildings and equipment which is likely to prove most formidable to the ratepayers' representatives. Nor are any substantial building grants to be expected from the Government unless a great deal more pressure is applied to the Treasury to carry into effect the very shadowy promise made in the House of Commons last spring.

Next to the deficiency of funds comes the difficulty of getting any proper co-operation between so many authorities, autonomous and often jealous of each other. Some inspiring and propelling force would seem to be required in many cases to effect the necessary combinations between counties and boroughs to establish training colleges. Possibly a lever towards this end may be found in the vaguely worded section of the Education Act which requires local education

authorities in forming their schemes of higher instruction to enter into 'consultation' with the Board of Education.

But the most serious difficulty of all lies in what may be called the 'localisation' of the individual teacher. The ratepayers who naturally wish to see their money's worth will put this question to their county councillor: 'If you rate me for sending teachers to a training college, what guarantee can you give me that they will return to teach in our schools, or that an equivalent number of teachers trained by other councils will do so?' This question can probably be answered with satisfaction to the ratepayer in the case of the metropolis and some other large towns and counties, where the salaries of the teachers and the conditions of their employment are all that they can desire. But it is different in the rural counties, where plenty of good material for training is to be found, but where the schools are small and salaries, even under the new conditions, are likely to be moderate. There is also some danger that certain local authorities may prefer to secure teachers trained elsewhere by the offer of high salaries rather than train them themselves. Unless, therefore, some State machinery is devised for requiring each local authority to contribute its proper quota towards such training—a course which at present seems impracticable—the local authorities, either individually or in combination, will have to bind each teacher they train to serve exclusively in their schools for a reasonable number of years. Such a system of indenture may be found financially necessary, but it does not seem educationally desirable, and its result must be seriously prejudicial both to the free circulation of educational energy and to the interests of the weaker counties and boroughs.

I have hitherto had in mind the training of teachers in training colleges from the age of eighteen and upwards; but it must be remembered that for a long time to come many of our elementary teachers, at all events, will require liberal facilities for training in special subjects elsewhere than at training colleges, and that the local authorities will be required to find funds both for this purpose and to supplement the Government grants for training pupil-teachers. This strengthens the case for throwing the cost of training colleges upon the national exchequer rather than on local rates.

There is one argument against centralisation which deservedly has some weight—viz., the desirability of encouraging local experiments and variety of curricula in the training colleges. But there seems no good reason why this object should not be secured by widening the field of Government grants and aiding equally various types of training courses, as was recommended to the Board by the Departmental Committee which sat in 1901. Equality of standard may be maintained through the Government inspectorate without imposing uniformity of teaching on institutions that ought to suit the different needs of town and country, of large and small schools.

In short, the present problem seems to be how to encourage and impel our local education authorities each to bear its fair share in the task of increasing the supply of competent teachers without forcing them all into one groove and depriving them of all initiative and independence.

Mr. H. Macan suggested that there should be two classes of teachers—one highly trained, for the permanent work and higher posts corresponding to the manager or foreman of a business, and other persons of good general education, without pretensions to training, but sufficiently qualified for the temporary work of teaching in the lower grades. Such a division would be consonant with a state of things in which such a large number of teachers left the profession at a comparatively early age and took up other employments. This was an economic necessity, and the number of assistants was out of all proportion to the number of well-paid higher posts to which they might aspire. All these lower-grade teachers should have another trade or profession at their back.

Mr. G. F. Daniell said that Mr. Hobhouse's paper was very comprehensive. There was need of better provision of men to teach in secondary schools, and such teachers must be trained. The number of secondary teachers required was relatively small, and if adequate salaries were offered the supply would respond to the demand. But the demand now was for good athletes, who are sure

to get a post in a good school; this encouraged athletics, and a demand for trained teachers might encourage training. Teaching should not be regarded as a passing occupation, but as a life work, and the training of teachers would tend to bring this about. It was very important that the conditions of service as a teacher should be improved. There should be a prospect of rising in the profession, and there should be more security of tenure.

Mr. Ernest Gray, M.P., said that the local authorities had no greater difficulty at present than that of providing their schools with an adequate staff of well-equipped teachers. They were counting the cost, and some of them had come to the conclusion that it was easiest to throw the cost of training on other authorities, and then attract the trained teacher by offering him a slightly higher salary. It was not desirable that the teaching staff should be mainly drawn from certain centres. No local authority ought to be allowed to escape from the obligation of training a certain number of teachers. But then came the question of cost, and the money available for the purposes of higher education, including the training of teachers, was not sufficient unless the localities rated themselves heavily. The charge now imposed by elementary education was so considerable that any further burden might lead to a reaction. It was, therefore, impossible to escape from the conclusion that the training of teachers should be a national charge. As might be expected, the local authority that trained teachers was now putting them under legal bond to serve in its schools; educationally this was most objectionable, and, from the point of view of the poorer counties, it would be disastrous if the authorities of the great cities were to follow the same policy. The time had arrived for the more scientific training of secondary school teachers. At present these teachers sometimes gained their experience at the expense of their pupils.

Dr. E. H. Cook pointed out the difficulties of the local authorities, and thought that in the great majority of cases they were performing an admittedly difficult task very well indeed. The question of the training of teachers was one of the most pressing troubles, in regard to which he thought the training colleges might improve their methods. In some cases teachers who had been 'hall-marked' as trained were found inefficient, and in other cases teachers had absolutely come back from training colleges less valuable as imparters of knowledge than when they entered. The cause of this was probably that in the curriculum of the ordinary training college a very short time—about six weeks or two months in the year—was devoted to instruction in the art of teaching. A certain amount of education was given, which was really that of the secondary school. For good training the practising schools should be carefully selected, and the actual teachers should be the best to be found, so that the pupils might study from the best examples and have fixed firmly in their minds the most effective methods of bringing out the latent powers of the children. The point referred to by Mr. Hobhouse, as to local authorities insisting that locally trained teachers should remain in the district in which they were trained, was in a great measure a ratepayers' question. It must not, however, be forgotten that the greater the number of local authorities who undertake the training of their own teachers, the less the difficulty in regard to localisation. Because, if A loses teachers to B, it would also gain from B, inasmuch as if B trains all it wants, then taking some from A will obviously give it an excess. In Bristol this view has been taken, and it has not been insisted upon that the locally trained teachers shall return to work in the city, notwithstanding that for some years now we have provided for many more pupil-teachers than we want. The training of secondary teachers was most important, as it was, unfortunately, the fact that a large number of such teachers, whilst good students and well stored with knowledge, could not impart that knowledge to others. Fortunately, we have in our university colleges centres which can be utilised for this purpose, and in the proper development of these institutions seemed to lie the solution of the difficulty of training secondary teachers.

Principal Griffiths said that the one important question was whether the training of teachers should be a national or a local undertaking. In Wales the present difficulty was about to be considered by a congress of all the education

authorities in the Principality, and the attempt was to be made to devise one scheme for the whole of Wales. It was most important that those who were training for the teaching profession should be associated with the students for other professions, and that the hard-and-fast division between primary and secondary teachers should be obliterated.

Mr. Culverwell said that to make the training of teachers a national rather than a local concern would secure a more immediate supply of trained teachers. But he doubted whether the former would be as effective as the latter in the long run. People took much more care in expending their own than national money, and the most important of all reforms in education was to increase and sustain the interest of the parents in the school. Moreover, central control was apt to get into the hands of doctrinaires, and it was extremely hard to reform a Government department when once it got wrong.

Mr. J. L. Holland drew attention to some of the dangers accompanying the administration of the new regulations for the training of pupil-teachers. The pupil teachers should not monopolise all the scholarships given in various areas. In some areas it was a fact that a clever pupil could not obtain a scholarship if he were not willing to become a teacher. The intending pupil-teachers should enter the secondary schools at twelve, and not at fourteen years of age, as some people, misreading the regulations, seemed to imagine. The proportion of intending pupil teachers in any one school should not be large. To found schools, as was being done in some places, entirely for the sake of their pupil-teachers would defeat the real object of the new regulations.

Sir John Gorst said that the question was how to increase the supply of competent teachers. That supply had been short before the Act of 1902 was passed, and it was much shorter now. The passing of an Act of Parliament did not create a body of teachers. It was most ridiculous to decide before the student was trained whether he was to be an elementary, a secondary, or a technical teacher, and he objected fundamentally to this attempt to divide education into these three watertight compartments. To suppose that anyone could be competent for one kind of teaching without any knowledge of the other kinds was a delusion. No doubt the supply of head-masters of public schools could be left to take care of itself; but to increase the great body of teachers it would be necessary to draw on a class which could not afford the necessary training without State help. There was no difficulty in obtaining teachers in Ireland. Why not recruit the teaching staff from that country? The system of training teachers which had hitherto obtained had been a disastrous failure, and a revolution was necessary. The burden laid on the young pupil-teacher was greater than anyone could bear, and he was never more indignant than when he heard Sir William Anson, in the House of Commons, reading out the ridiculous answers which pupil-teachers had given in examinations. Such answers were the exact result to be expected from the system now pursued. Assistance for the training of teachers must be given both from Imperial and from local funds; but he was opposed to the old-fashioned training college, where students for the teaching profession were completely isolated. The whole training of the teachers could be supplied in such existing educational institutions as the county schools and the universities, if the Government gave adequate grants. The qualification of the teacher should be certified to by the university, and not by a Government department, and invidious distinctions between one class of teachers and another should be avoided. Then the profession of teaching might offer an honourable career.

Mr. Oscar Browning: One of the worst enemies of the training of teachers is to be found in the curricula which are from time to time sent to us by the Board of Education. Whenever it occurs to anyone that some subject ought to be taught in the elementary schools, an attempt is made to force it upon the teachers who are in training and to make it part of the training-college course. Surely it is only important that the teacher should be a well-educated man, and it may fairly be claimed that the University Training Colleges of Oxford and Cambridge have fulfilled this end. The Cambridge College has now been at work for twelve years—only two years less than the limit given by a previous speaker to the

average life of a male teacher. Sir William Anson said the other day in the House of Commons that pupil-teachers were, as a whole, not competent to take university degrees. Speaking with a considerable knowledge of public schools, I can confidently assert that they are just as fit to take these honours as the average public-school boy, and in some cases much more fit. The list I hold in my hand contains three first classes, including a nineteenth wrangler, eight second classes, and three third classes, a record which might do honour to many a Cambridge college. It is also objected that our students are not trained to be elementary teachers, but that they drift into secondary teaching. This we do not find to be the case. During the twelve years' existence of the College only three students have given up education altogether, and only twelve, or an average of one a year, are now engaged in secondary education, and these have satisfied their obligation by serving in most cases as elementary teachers. I therefore maintain that the pupil-teachers we receive, who are by no means a picked or selected lot, are fully competent to profit by a university education, and that they do, when so trained, continue to be elementary teachers. We have also tried the experiment of training primary and secondary teachers together. We were the first to do this, and our example has been imitated elsewhere. We find that this condition is indispensable to our success, and that both classes of teachers gain largely by being trained together.

M. Emile Hovelaque said that he had extreme diffidence in speaking on a subject mainly administrative and wholly English, but he was encouraged to do so by the protests which had been made against introducing any narrow and parochial spirit into the training of the teachers. If it were desirable that teachers from one part of the country should have experience in other parts, might it not be equally desirable for teachers to have experience of foreign countries? In France there had recently been instituted a scheme which, though not primarily designed for the training of teachers, might easily be made to work in with that object. In the French universities, secondary schools, and training colleges it was now the practice to have foreign visitors in residence, and their business was not to teach, but to give to advanced pupils the benefit of opportunities for unconstrained conversation and for deriving accurate and living impressions of foreign countries. It was found that this informal intercourse with foreigners was much more instructive for the students than any conversation with or teaching by the regular professors. It would be a great advantage if a larger number of English students for the higher branches of the teaching profession could be induced to take up residence in this way at the French schools and colleges, where they would receive free board and lodging in exchange for a few hours' conversational work a day. The advantage to the English student would be great, because he would not only be able to learn the French language, but he would have every opportunity of studying the methods of teaching practised in the French educational institutions. In regard to the teaching of the mother-tongue, the example would be especially valuable, for particular attention had been devoted to that subject in France; and in England the teaching of English had been surprisingly neglected. The scheme, it should be noted, was not one for international exchange of secondary school teachers, but rather for the interchange of those who in the future were intending to become teachers in secondary schools.

Miss Edna Walter said that it was useless to consider how to increase the supply of teachers without increasing the rewards of the profession. Instead of giving bursaries and scholarships to attract young people into the profession, it would be better to spend the money in increasing the salaries of teachers, so as to keep them in the profession.

The Rev. W. T. A. Barber laid emphasis on the necessity of a broadening element in the training of elementary teachers. He mentioned an experiment which is being worked out in the Eastern Counties. Intending teachers are removed at twelve, on scholarships, to secondary schools; are there mixing with children of another social style till eighteen, and then, all school subjects laid on one side, are sent for a single year of pedagogics to a training college. The train-

ing accommodation will thus be at once doubled. In the training of secondary teachers now made necessary by the registration conditions the great difficulty is to get any teachers to train. The superior attractions of the Civil Service, the professions and business, practically leave no first-class men for schoolmastering. It is not easy to add another costly year to the costly training which already attracts so few. All training must be in connection with some university centre, and a great future is to be anticipated for the Cambridge Training School, where secondary and primary teachers are taught together. Experience shows the difficulty of a practising-ground for the secondary teachers, for classes in primary schools are often entirely unlike those in secondary.

The Rev. J. F. Tristram said that he protested against the light-hearted suggestions made concerning the training of secondary teachers. Those who thought that it would be wise to send into our secondary schools men and women who had had no special preparation for their duties, 'and see how their new ideas would work,' and those who believed it unwise to differentiate the training of elementary and secondary teachers, but to 'see what sort of teachers they would turn out to be' after a generalised course of training, were not good guides at the present crisis. They forgot the facts. Teaching was becoming more and more a highly specialised craft, demanding peculiar gifts and a laborious apprenticeship, and the difference between the subject-matter of the education of those attending primary and higher schools surely required a different training. This divergence was not likely to diminish, but to increase. As for the expedients for attracting children of a lower social class into the ranks of secondary teaching, to remedy the great and increasing demand for recruits, he had the gravest doubts of its success and of its influence upon our public schools, and demanded that the ordinary commercial law of supply and demand should be applied to the profession, saying that the attractions of other careers than teaching would always take away the most promising young people until the remuneration offered by this profession should be raised and the conditions of tenure should be rendered more reasonable. This surely was the way to attract better and more recruits, and until the supply were increased in this honest and natural way the talk about methods of training was idle, because there would be no candidates for the teaching profession to be trained.

Dr. Mangold said that in Germany elementary and secondary teachers were trained separately and differently. Financial difficulties would diminish if the training of secondary teachers was entrusted to prominent masters as an additional work, and paid accordingly. The most important thing was practical training. Pupil-teachers ought to see the imparting of knowledge by excellent masters.

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2. *The Research Method applied to Experimental Teaching.* *By* Professor H. E. Armstrong, *LL.D., F.R.S.*

Dr. Armstrong insisted at the outset that no other method was possible; that merely to follow directions, as is done in so much of our laboratory work, is not experimenting in any sense of the term. The practical verification by students of statements brought under their notice often affords valuable discipline in manipulation, and it may bring facts home and fix them in the memory in a way not otherwise possible; but such teaching does not serve to develop in any proper way logical habits of thought and alertness of mind, nor does it serve to cultivate the spirit of inquiry.

Rightly viewed, an experiment has three stages: (1) the stage of conception; (2) that of performance; (3) that of utilisation. Of these the second is relatively very easy; but it is the mere mechanical bridge between the first and third, and yet, as a rule, it all but monopolises the attention of the student. It is essential that in every experiment there should be some clearly defined purpose or motive in view, some definite problem to be solved; that some question should be asked from the outset for which an answer can be sought. Then must come the question whether any clue can be found and worked upon. The best way of making the

experiment must next be thought out gradually in every detail. During the experiment everything that is noticeable or that happens must be most carefully recorded. Finally, the results obtained must be interpreted in the light of the question asked, and they must be utilised as stepping-stones towards the further prosecution of the inquiry. It is because students so rarely make 'experiments' with any clearly conceived purpose in view that we have made so little progress hitherto in making 'science' an effective educational discipline.

Dr. Armstrong dwelt on the impropriety of adopting the Euclidian method of stating the answer in advance, so usual among teachers. He insisted on the need of writing down as the work proceeds (*a*) the complete argument on which the experiment is based; (*b*) everything that is done *as it is done*; (*c*) the observations made; (*d*) every inference that can be drawn from the observations, both those bearing on the original problem and also those which serve to raise new issues. He further insisted that the writing of such records was of supreme value as a literary exercise, and that experimental teaching could not be conducted properly with the object of giving training in the art of inquiry unless it were combined with careful instruction in the art of composition. Taking limestone by way of example, he pointed out at length why it should be studied, and how it might be studied, following the lines laid down in the well-known British Association programmes, which have been more fully developed in his book on the 'Teaching of Scientific Method' (Macmillan).

TUESDAY, AUGUST 23.

The following Paper and Reports were read:—

1. *Discussion on Methods of Imparting Manual Instruction in Schools. Opened by* Sir PHILIP MAGNUS, *B.Sc.*

It was at the meeting held in Birmingham in 1886, long before the Educational Science Section existed, that I had the privilege of first bringing under the notice of the Association the subject of manual training as a part of general education. Since then great strides have been made. The Association of Manual Training Teachers, of which till last year I was President, has done much to improve the method of teaching in our public elementary schools. It was, however, to the joint committee, composed of representatives of the City Guilds' Institute and the Drapers' Company, which supplied the funds, and of the late School Board for London, which gave the use of its rooms, that the introduction of this subject into our schools and its recognition by the Board of Education are mainly due.

One reason for the rapid appreciation of the value of manual instruction as a part of the curriculum of school teaching was that we were fortunate enough to adopt from the first in the teaching of the subject a correct method, based on sound educational principles. This was not so in science teaching, in which the aim of the teaching for many years was information as to facts—facts which might be learned from any text-book. Hence we had far less to unlearn in manual instruction than we had in science teaching. We had to resist the too utilitarian tendency of educational effort a decade since to make manual instruction the means of teaching in school a trade; but we did resist it. From the first we recognised that such teaching must be a *discipline*—a means of exciting intellectual activity through manual work, and of bringing children's minds into direct contact with real things. Incidental advantages were soon found to follow from the methods of teaching first adopted. It was demonstrated as a fact that the instruction made all children generally more intelligent, quicker at their mental work, and more resourceful; and whilst the time taken from other studies in no way impeded the children's progress in those studies, but, on the contrary, quickened their grasp of new ideas, the special teaching was found to excite the interest of such children as showed signs of possessing a particularly lethargic

temperament, and to stimulate them, as nothing else had done, to work at other things. This was the great advantage of manual teaching.

The difficulty at first experienced, and now by no means wholly overcome, was the supply of competent teachers. As a matter of educational principle, the teachers should be the ordinary school teachers. It was recognised at first, by those who had the direction of manual instruction, that to insure good methods the instruction should be given by highly trained teachers, and that the village carpenter or blacksmith would not make a competent instructor. For this reason the City Guilds' Institute, which was the first body to give a certificate of competency to teachers, admitted to its examinations none other than certificated teachers in elementary schools. But the pressure of opinion, the practice of the late School Board for London, and the demand for teachers, which rapidly overtook the supply, compelled the Institute to widen the door of admission to its examination. Moreover, the Institute was not averse from trying the double experiment of training educated teachers in manual work, and of training skilled artisans in the methods of instruction. Both experiments have been attended with fairly satisfactory results, although it must be admitted that, however the teacher may have been trained, it is essential that he should be first of all well educated and skilled in the methods of imparting knowledge, in order that manual work may become an integral part of the school curriculum, and may be closely associated with the teaching of other subjects of the school course.

It is not until we recognise the fact that many subjects of instruction may be taught in connection with workshop training, and that the methods of the workshop may be made applicable to the teaching of other subjects, that manual instruction will have found its proper place in our elementary and higher schools.

To this end the instruction must be continuous from the early Kindergarten exercises till the boy or girl leaves the school. Hitherto the material employed in manual instruction has been wood and iron. But if the instruction is to be continuous, other materials and other methods than those at present adopted must be employed. The manual instruction must be made the means of progressively developing the child's intelligence, and of providing subjects for inquiry and thought in the region of elementary geometry, arithmetic, and mensuration, and to some extent in the rudiments of natural and experimental science, from the earliest age throughout the child's entire school career. This is essential, and this fundamental proposition must dominate and determine methods of imparting manual instruction in all types of schools.

Accepting this general proposition, we see how small a part of the manual training field has, so far, been systematically surveyed. We have to remember that at present the course of manual instruction in all our schools is discontinuous and broken. Between the age when Kindergarten exercises cease and the time when a boy is fit to pass to wood-working tools, *i.e.*, roughly, between the ages of eight and eleven, a boy receives no instruction by manual methods, except perhaps in drawing, and relies almost exclusively upon oral teaching. This *lacuna* in his practical education has to be filled in. Methods of instruction have to be discovered and materials for workshop exercises have to be suggested which will serve for this unexplored interval—from the time he leaves the infant school till he is qualified to enter the ordinary school workshop. In connecting these two periods care must be taken that the secondary influence of manual instruction shall also be continuous—that the training in observation, measurement, and reasoning shall be developed by appropriate exercises for each successive year.

In the training of girls much has to be done in this direction. Without favouring early specialisation, I cannot arrive at any other conclusion than that manual instruction should be different, not in aim, but certainly in subject, for the two sexes. Except as regards sewing, which although in some cases useful for boys, is essential for girls, the manual instruction for girls, from eleven or twelve years onwards, should be largely, if not entirely, associated with the domestic arts. In cookery and in needlework, and generally in subjects relating to household management, there is ample scope for that practical teaching, that workroom training which may be made to yield the same educational discipline

as wood-work and metal-work afford to boys. We cannot escape from the conclusion that education must be, in the first place, individual, and prepare us for complete living. For this reason the subjects of instruction must be selected with reference to the usefulness of the training in the discharge of the primary duties of life. We have yet to show how the different branches of domestic economy, as it is generally called, may be taught so as to serve as a centre of interest for the acquisition of knowledge of other cognate subjects and as a rigorous exercise in the practice of scientific method. Progressive schemes of instruction have to be elaborated suitable for different types and grades of girls' schools. But in all such schemes the aim and purpose must be educational, and not professional. The method of instruction should be such that the girl may grow in intelligence and resourcefulness, may have her interests enlarged and her general knowledge widened, whilst at the same time she is acquiring that special skill in the domestic arts which is essential to her well-being and will increase her usefulness in every womanly occupation in which she may be engaged. Underlying the domestic arts are scientific principles, the roots of which stretch out wide and far. The scheme of instruction, therefore, which should vary with the age when the child leaves school, should carefully associate theory with practice, and should show in detail the kind of experiments that the child should perform in order to acquire that amount of accurate scientific knowledge which will be helpful in her work. Under good instruction there should be no learning by heart useless scraps of information, to be reproduced verbatim without any intelligent understanding of the meaning of the terms employed, and with very varied spelling.

No; the methods of manual instruction, some of which have to be worked out, must be the same for boys and girls. The aims of the teaching should also be identical; but the subject-matter should be such as has some relation to the future life-work of each sex, and this differentiation should commence when the child is about eleven years old.

My observations have been limited to manual work as it should be taught from the close of the Kindergarten to the end of a child's elementary school course. Our chief aim should be to make this instruction continuous. After the elementary school age, the instruction in certain types of school tends to become professional in character. This kind of teaching has become fully developed in France and in the United States; but I do not propose to discuss it now. In ordinary secondary schools a somewhat different kind of instruction has to be considered, but the method does not differ essentially from that of the lower school. It is satisfactory to find that manual instruction is now a recognised part of the training-college course. But the subject is treated somewhat as an intruder, and sufficient time is not yet given to it. The introduction of such teaching, however, is likely to exercise a very beneficial influence on the methods of teaching other subjects. This fact has only now begun to be realised, and important and at present unforeseen consequences are likely to follow.

Mr. Millis expressed his belief that opposition on the part of trade unions was frequently a sign that the manual training was either improperly done or improperly explained. He had known cases in which the fitting up of a manual-training (metal) workshop had been an attempt to copy the fittings of an engineer's shop, and years ago much harm was done by talking about the teaching of carpentry, instead of the giving of instruction in manual woodwork, and carpenters then frequently asked why theirs should be the only trade taught. Mr. Millis further added that he was certain that if manual training was given in connection with other school subjects, and not treated as a special subject outside school work, opposition from trade unions would cease to exist. Manual training should be connected with drawing, drawing with geometry, geometry with arithmetic, and then we should get much better educational results.

Mr. Oscar Browning said that he wished to bear testimony to the value of manual training as a part of education. He had been led to this opinion in the first instance by the teachings of Rousseau and Goethe. He believed that every member of the House of Hohenzollern was taught a trade, the present German Emperor having been taught bookbinding. As an Eton master he had learnt

that some boys could not be intellectually educated except through their own hands. Some boys could not be affected by books or by abstract ideas. On the other hand, if you set them to *do* something, they will be led to abstract ideas. If you set boys to use their hands they would soon begin to use their heads. This had been shown by the Mechanical Sciences Tripos, the pupils of which were singularly active and intelligent in all respects.

Mrs. Marvin held that women themselves were to blame if they were not consulted about the drawing up of schemes of manual instruction for girls. If they showed sufficient interest in the matter they could have it all their own way. She held that the manual training of girls should *not* be restricted to the domestic arts. The domestic occupations were mostly poor as a training in manual strength and skill. Girls were generally found to be inferior to boys in dexterity and accuracy of hand, and many competent judges attributed this largely to their unfamiliarity with the great variety of tools and objects with which a boy busies himself. She would enlarge the scope of girls' manual training, using specially various artistic occupations. At the same time, the domestic arts as usually taught in schools were capable of being greatly improved as a means of manual training; sewing, *e.g.*, as now taught, was often little more than the making of stitches; it might be made a valuable discipline.

Dr. Walmsley said that there was a danger in manual training of not following out the professed ideals, but of allowing the training to become a means of teaching trades. In America, schools of manual training were more developed than here, but the American schools must not be confused with ours. The presidents of the schools might have the same ideals as ourselves, but the teachers carried these out in a very different manner. The effect of their teaching was to turn out artisans, and they taught things which possessed no educational value. It was difficult to obtain the right kind of teachers and of teaching. We must be very careful that the ideals are properly carried out, and the aim in view must never be forgotten.

Miss Cooper hoped that the appeal made to women would be fully responded to. We want the co-operation of both sexes. With regard to girls, we must study what to put in and what to leave out. We must not forget domestic arts and crafts. Take the art of stitchery; the employment of the needle had come down to use from prehistoric times. It might be connected with many other things, such as weaving and dress in general. Needlework should also be connected with literature and history, and thus be made a foundation for artistic and historical study. Indeed, the study of the needle crafts might be an education in itself.

Miss Maud Taylor differed from the remarks of two speakers; first, with the statement that women were not interested in the manual instruction of girls. In her experience women of all classes were most interested, and anxious to improve the existing conditions of such education, but were unable to escape from the cramping regulations of the Education Department. She pointed out the impossibility of teaching genuine household economy and management under the present elementary school system, by which girls received only two or three hours' instruction per week. Any practical housewife understands that such instruction must deal only with individual items of knowledge and omit management as a whole. The price of the food and the cost per head of dishes cooked were worked out in all schools with which she was acquainted. The Domestic Economy Centres, under the London School Board, are at present giving the best (because consecutive) courses of such instruction.

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2. *Interim Report on the Course of Experimental, Observational and Practical Studies most Suitable for Elementary Schools.*

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3. *Report on the Conditions of Health Essential to the Carrying-on of the Work of Instruction in Schools.*—See Reports, p. 348.

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References to reports and papers printed in extenso *are given in Italics.*
*An asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but a reference is given to the Journal or Newspaper where the paper is published in extenso.

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PRESIDENTS OF FORMER YEARS.

Sir Joseph D. Hooker, G.C.S.I.
Lord Kelvin, G.C.V.O., F.R.S.
Lord Avebury, D.C.L., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir Wm. Huggins, K.C.B., Pres.R.S.
Sir Archibald Geikie, Sec.R.S.
Prof. Sir J. S. Burdon Sanderson, Bart., F.R.S.
Lord Lister, D.C.L., F.R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.
Sir Michael Foster, K.C.B., F.R.S.
Sir W. Turner, K.C.B., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Sir J. Dewar, LL.D., F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, D.C.L., F.R.S.
Sir Michael Foster, K.C.B., F.R.S.
P. L. Sclater, Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
A. Vernon Harcourt, F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.
Prof. E. A. Schäfer, F.R.S.
Dr. D. H. Scott, M.A., F.R.S.
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.

AUDITORS.

E. W. Brabrook, Esq., C.B. | H. Higgs, Esq., LL.B.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1904.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report for 1904.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant Secretary, Burlington House, W.

Year of Election.

1887. *ABBE, Professor CLEVELAND. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1897. ‡Abbott, A. H. Brockville, Ontario, Canada.
1898. §Abbott, George, M.R.C.S., F.G.S. 33 Upper Grosvenor-road, Tunbridge Wells.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1902. ‡ABERCORN, The Duke of, K.G. Barons Court, Ireland.
1885. *ABERDEEN, The Earl of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Pres. L, 1903; Council, 1884–89, 1902– .) Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.
1886. ‡Abraham, Harry. 147 High-street, Southampton.
1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1900. §Ackroyd, William. Borough Laboratory, Crossley-street, Halifax.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, S.W.

Year of Election.

1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.
1873. *Acland, Rev. H. D., M.A. Lamorva, Falmouth.
1894. *Acland, Henry Dyke, F.G.S. Lamorva, Falmouth.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston-square, W.
1904. §Acton, T. A. 3 Grove-road, Wrexham.
1898. ‡*Acworth, W. M. 47 St. George's-square, S.W.*
1901. ‡Adam, J. Miller. 15 Walmer-crescent, Glasgow.
1887. ‡ADAMI, J. G., M.A., M.D., Professor of Pathology in McGill University, Montreal, Canada.
1892. ‡Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1901. ‡Adams, John, M.A. 12 Holyrood-crescent, Glasgow.
1871. ‡Adams, John R. 2 Nutley-terrace, Hampstead, N.W.
1904. §Adams, W. G. S., M.A. Owens College, Manchester.
1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council 1878–85), Professor of Natural Philosophy and Astronomy in King's College, London. 43 Campden Hill-square, W.
1901. ‡Adamson, P. 11 Fairlie Park-drive, Glasgow.
1896. ‡Adamson, W. Sunnyside House, Prince's Park, Liverpool.
1898. ‡Addison, William L. T. Byng Inlet, Ontario, Canada.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡ADENEY, W. E., D.Sc., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1899. §Adie, R. H., M.A., B.Sc. 136 Huntingdon-road, Cambridge.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1902. ‡Agnew, Samuel, M.D. Bengal-place, Lurgan.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §AITKEN, JOHN, LL.D., F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1901. §Aitken, Thomas, M.Inst.C.E. County Buildings, Cupar-Fife.
1898. ‡AKERS-DOUGLAS, Right Hon. A., M.P. 106 Mount-street, W.
1884. *Alabaster, H. Milton, Grange-road, Sutton, Surrey.
1886. *Albright, G. S. Broomesberrow Place, Ledbury.
1904. *Allcock, William Burt. Emmanuel College, Cambridge.
1900. *Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1894. ‡Alexander, A. W. Blackwall Lodge, Halifax.
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. Pinehurst, Mytclett, Farnborough, Hants.
1896. ‡Alexander, William. 45 Highfield South, Rockferry, Cheshire.
1891. *Alford, Charles J., F.G.S. 15 Great St. Helens, E.C.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, E.C.
1901. *Allan, James A. Westerton, Milngavie.
1879. *Allen, Rev. A. J. C. 34 Lensfield-road, Cambridge.

Year of
Election.

1898. §ALLEN, Dr. E. J. The Laboratory, Citadel Hill, Plymouth.
1888. ‡ALLEN, F. J., M.A. 108 Mawson-road, Cambridge.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, S.W.
1887. ‡Allen, John. 14 Park-road, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 28 Great Ormond-street, W.C.
1889. ‡*Allhusen, Alfred. Low Fell, Gateshead.*
1896. ‡Alsop, J. W. 16 Bidston-road, Oxton.
1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D., F.R.S. Hornton Lodge, Hornton-street, Kensington, W.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. Care of Messrs. J. Evans & Co., Bute Docks, Cardiff.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid, Ashburton, Devon.
1884. ‡AMI, HENRY, M.A., D.Sc., F.G.S. Geological Survey, Ottawa, Canada.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *ANDERSON, HUGH KERR. Caius College, Cambridge.
1901. *Anderson, James. Ravelston, Kelvinside, Glasgow.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1899. *Anderson, Miss Mary Kerr. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 5 Westminster-chambers, S.W.
1887. ‡ANDERSON, Professor R. J., M.D., F.L.S. Queen's College, and Atlantic Lodge, Salthill, Galway.
1889. ‡Anderson, R. Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc., F.G.S. (Local Sec. 1881.) 17 Stonegate, York.
1902. *Anderson, Thomas. Embleton, Osborne Park, Belfast.
1901. *Anderson, Dr. W. Carrick. 2 Florentine-gardens, Glasgow.
1901. ‡Anderson, W. F. G. 47 Union-street, Glasgow.
1895. ‡Andrews, Charles W. British Museum (Natural History), S.W.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.
1900. ‡Annandale, Nelson. 34 Charlotte-square, Edinburgh.
1896. ‡Annett, R. C. F. 4 Buckingham-avenue, Sefton Park, Liverpool.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1901. ‡Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1900. §Arber, E. A. Newell, M.A., F.L.S. Trinity College, Cambridge.
1898. ‡*Archer, G. W.* 11 *All Saints'-road, Clifton, Bristol.*
1894. ‡Archibald, A. The Bank House, Ventnor.
1884. *Archibald, E. Douglas. 32 Shaftesbury-avenue, W.
1883. §Armistead, Richard. 17 Chambres-road, Southport.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1903. *ARMSTRONG, Dr. E. FRANKLAND. 55 Granville-park, Lewisham, S.E.

Year of Election.

1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S. (Pres. B, 1885; Pres. L, 1902; Council 1899-), Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville-park, Lewisham, S.E.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1901. ‡Arthur, Matthew. 78 Queen-street, Glasgow.
1904. §Arunáchalam, P. Ceylon Civil Service, Colombo, Ceylon.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1903. *Ashby, Thomas, jun. The British School, Rome.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. ‡Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
Ashworth, Henry. Turton, near Bolton.
1903. §Ashworth, J. H., D.Sc. 4 Cluny-terrace, Edinburgh.
1888. *Ashworth, J. Jackson. Kingston House, Didsbury, near Manchester.
1890. ‡Ashworth, J. Reginald, D.Sc. 105 Freehold-street, Rochdale.
1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Ashworth, Mrs. J. W. Thorne Bank, Heaton Moor, Stockport.
1875. *Aspland, W. Gaskell. Tuplins, Newton Abbot.
1896. *Assheton, Richard. Grantchester, Cambridge.
1903. §Atchison, Arthur F. T., B.Sc. Royal Engineering College, Cooper's Hill, Staines.
1896. §Atkin, George, J.P. Egerton Park, Rockferry.
1887. §Atkinson, Rev. C. Chetwynd, D.D. Ingestre, Ashton-on-Mersey.
1898. *Atkinson, E. Cuthbert. Care of C. W. Atkinson, Esq., 31 Manor-road, Beckenham, Kent.
1894. ‡Atkinson, George M. 28 St. Oswald's-road, S.W.
1894. *Atkinson, Harold W. Boys' High School, Pretoria, South Africa.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S. (Local Sec. 1891.) 44 Loudoun-square, Cardiff.
1894. §Atkinson, William. Erwood, Beckenham, Kent.
1863. *ATTFIELD, J., M.A., Ph.D., F.R.S., F.C.S. Ashlands, Watford, Herts.
1884. ‡Auchincloss, W. S. Atlantic Highlands, New Jersey, U.S.A.
1903. ‡AUSTIN, CHARLES E. 37 Cambridge-road, Southport.
1853. *AVEBURY, The Right Hon. Lord, D.C.L., F.R.S. (PRESIDENT, 1881; TRUSTEE, 1872- ; Pres. D, 1872; Council 1865-71.) High Elms, Farnborough, Kent.
1901. ‡Aveling, T. C. 32 Bristol-street, Birmingham.
1877. *AYRTON, W. E., F.R.S. (Pres. A, 1898; Council 1889-96), Professor of Electrical Engineering in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W., 41 Norfolk-square, W.

1884. ‡Baby, The Hon. G. Montreal, Canada.
1900. ‡BACCHUS, RAMSDEN (Local Sec. 1900). 15 Welbury-drive, Bradford.
1883. *Bach, Madame Henri. 19 Avenue Bosquet, Paris.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1903. §Baden-Powell, Major B. 22 Prince's-gate, S.W.
1883. ‡Bagnold, Mrs. Berkeley House, High Park, Ryde, Isle of Wight.

Year of Election

1883. ‡Baildon, Dr. 42 Hoghton-street, Southport.
1892. ‡Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Atherstone House, North-drive, St. Anne's-on-the-Sea, Lancashire.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. 7 Drummond-place, Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1899. ‡Bailey, T. Lewis. Fernhill, Formby, Lancashire.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1894. *Baily, Francis Gibson, M.A. 11 Ramsay-garden, Edinburgh.
1878. ‡Baily, Walter. 4 Roslyn-hill, Hampstead, N.W.
1897. §Bain, James. Public Library, Toronto, Canada.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *Baker, Sir Benjamin, K.C.B., K.C.M.G., LL.D., D.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1885; Council, 1889–96.) 2 Queen Square-place, Westminster, S.W.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland-lane, Runcorn.
1893. ‡Baker, Herbert M. Wallcroft, Durdham Park, Clifton, Bristol.
1898. ‡Baker, Hiatt C. Mary-le-Port-street, Bristol.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡Baker, W. Proctor. Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Warshill Vicarage, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1904. §Balfour, The Right Hon. A. J., D.C.L., LL.D., M.P., F.R.S., Chancellor of the University of Edinburgh. (President.) 10 Downing-street, S.W.
1871. ‡Balfour, The Right Hon. G. W., M.P. 24 Addison-road, Kensington, W.
1894. §Balfour, Henry, M.A. (Pres. H., 1904.) 11 Norham-gardens, Oxford.
1875. ‡Balfour, Isaac Bayley, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S., (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *Ball, Sir Robert Stawell, LL.D., F.R.S., F.R.A.S. (Pres. A, 1887; Council 1884–90, 1892–94; Local Sec. 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, B.Sc. 3 Albany-street, Glasgow.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.
1898. ‡Bannerman, W. Bruce, F.R.G.S., F.G.S. The Lindens, Sydenham-road, Croydon.
1866. ‡Barber, John. Long-row, Nottingham.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1902. ‡Barcroft, H., D.L. The Glen, Newry, Co. Down.

Year of Election.

1902. ‡Barcroft, Joseph, M.A., B.Sc. King's College, Cambridge.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1904. §Barker, B. T. P. Fenswood, Long Ashton, Bristol.
1899 §Barker, John H. 2 Collingwood-street, Newcastle-on-Tyne.
1882. *Barker, Miss J. M. The Fox Covers, Bebington, Cheshire.
1879. *Barker, Rev. Philip C., M.A., LL.B. Priddy Vicarage, Wells, Somerset.
1898. §Barker, W. R. 106 Redland-road, Bristol.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. Fordwich House, Sturry, Kent.
1889. ‡Barlow, H. W. L., M.A., M.B., F.C.S. The Park Hospital, Hither Green, S.E.
1883. ‡Barlow, J. J. 84 Cambridge-road, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in St. Mungo's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
1885. *Barlow, William, F.G.S. The Red House, Great Stanmore.
1902. §Barnard, J. E. Lister Institute of Preventive Medicine, Chelsea-gardens, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1904. §Barnes, Rev. E. W., M.A., F.R.A.S. Trinity College, Cambridge.
1889. ‡Barnes, J. W. Bank, Durham.
1899. ‡Barnes, Robert. 9 Kildare-gardens, Bayswater, W.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1901. ‡Barnett, P. A. Pietermaritzburg, South Africa.
1899. ‡Barnett, W. D. 41 Threadneedle-street, E.C.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E., Professor of Civil Engineering in the University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1902. *Barr, Mark. The Cedars, Cowley, Middlesex.
1891. ‡Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1904. §Barrett, Arthur. 6 Mortimer-road, Cambridge.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1872. *Barrett, W. F., F.R.S., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Abbotsgate, Huyton, near Liverpool.
1899. ‡Barrett-Hamilton, Captain G. E. H. Kilmannock House, Arthurstown, Waterford, Ireland.
1887. ‡Barrington, Miss Amy. 18 Bradley-gardens, West Ealing, W.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. *Barrow, George, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.

Year of Election.

1858. ‡Barry, Right Rev. Alfred, D.D., D.C.L. The Cloisters, Windsor.
1883. ‡*Barry, Charles E. 1 Victoria-street, S.W.*
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, Sir G. C. T., K.C.B., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1852. ‡Barton, James, B.A., M.Inst.C.E. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1904. *Bartrum, C. O., B.Sc. 3 Holford-road, Hampstead, N.W.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1888. *Basset, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. (Pres. F, 1894.) 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, W.
1883. ‡Bateman, Sir A. E., K.C.M.G., Controller-General Statistical Department, Board of Trade, 7 Whitehall-gardens, S.W.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡Bateson, William, M.A., F.R.S. (Pres. D, 1904.) St. John's College, Cambridge.
1881. *Bather, Francis Arthur, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1863. §Bauerman, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1904. §Baugh, J. H. Agar. 92 Hatton-garden, E.C.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. ‡Bayly, F. W. 8 Royal Mint, E.
1875. *Bayly, Robert. Torr Grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Winterdyne, Chine Crescent-road, Bournemouth.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *Beale, Lionel S., M.B., F.R.S. 6 Bentinck-street, Manchester-square, W.
1884. ‡Beamish, G. H.M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. Oxford.
1889. §Beare, Professor T. Hudson, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1904. §Beasley, H. C. 25a Prince Alfred-road, Wavertree, Liverpool.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.

Year of Election.

1902. ‡Beatty, H. M., LL.D. Ballymena, Co. Antrim.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1886. ‡Beaugrand, M. H. Montreal, Canada.
1900. ‡Beaumont, Professor Roberts, M.I.Mech.E. The University, Leeds.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *BEAUMONT, W. W., M.Inst.C.E. Outer Temple, 222 Strand, W.C.
1896. ‡Beazer, C. Hindley, near Wigan.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1904. §Beckit, H. O. Balliol College, Oxford.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. (Council, 1870–75.) The Chantry, Bradford-on-Avon.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1904. *Bedford, T. G., M.A. 9 Victoria-street, Cambridge.
1891. ‡Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1901. *Beilby, G. T. 11 University-gardens, Glasgow.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L , M.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 17 Lansdowne-crescent, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. British Museum, S.W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡BELL, Rev. GEORGE CHARLES, M.A. Marlborough College, Wilts.
1900. *Bell, H. Wilkinson. Holmehurst, Rawdon, near Leeds.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. 52 Cromwell-road, Hove, Brighton.
1896. ‡Bell, James. Care of the Liverpool Steam Tug Co., Limited, Chapel-chambers, 28 Chapel-street, Liverpool.
1871. *BELL, J. CARTER, F.C.S. The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 102 Leyland-road, Southport.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1904. §Bellars, A. E. Magdalene College, Cambridge.
1893. ‡BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1904. *Bemrose, H. Arnold. Ash Tree House, Derby.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc., Professor of Biology in the University of Otago, New Zealand.
1891. ‡*Bennett, Alfred Rosling.* 44 *Manor Park-road, Harlesden, N.W.*
1896. ‡Bennett, George W. West Ridge, Oxton, Cheshire.
1881. ‡Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. §Bennett, Professor Peter. 6 Kelvinhaugh-street, Sandyford, Glasgow.
1896. ‡Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.

Year of Election.

1903. §Benson, D. E. 18 Lansdowne-road, Southport.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1901. *Benson, Miss Margaret J., D.Sc. Royal Holloway College, Egham.
1887. *Benson, Mrs. W. J. Care of W. J. Benson, Esq., Standard Bank, Johannesburg, Transvaal.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1904. §Bentley, B. H. University College, Sheffield.
1897. ‡Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1901. ‡Bergins, Walter L. 8 Marlborough-terrace, Glasgow.
1894. §Berkeley, The Right Hon. the Earl of, F.G.S. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1898. §Berridge, Miss C. E. 17 Rotunda-terrace, Cheltenham.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1904. §Berry, R. A. 5 St. Mary's-passage, Cambridge.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1882. *Bessemer, Henry. Moorlands, Bitterne, Southampton.
1890. ‡*Best, William Woodham.* 31 *Lyddon-terrace, Leeds.*
1880. *BEVAN, Rev. JAMES OLIVER, M.A., F.S.A., F.G.S. Chillenden Rectory, Dover.
1904. *Bevan, P. V., M.A. Garden-walk, Chesterton, Cambridge.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1903. ‡Bickerdike, C. F. 1 Boveney-road, Honor Oak Park, S.E.
1870. ‡*Bickerton, A. W. Newland-terrace, Queen's-road, Battersea, S.W.*
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *BIDWELL, SHELFORD, Sc.D., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1904. §Bigg-Wither, Colonel A. C. Tilthams, Godalming, Surrey.
1898. ‡Billington, Charles. Studleigh, Longport, Staffordshire.
1901. *Bilsland, William, J.P. 28 Park-circus, Glasgow.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Buxton.
1884. *Bingham, Colonel Sir John E., Bart. West Lea, Ranmoor, Sheffield.
1881. ‡BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. (Pres. G, 1900). 77 Ladbroke-grove, W.
1900. ‡Bird, F. J. Norton House, Midsomer Norton, Bath.
1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Penrhyn, Irlams o' th' Height, Manchester.
1904. §Bishop, A. W. Edwinstowe, Chaucer-road, Cambridge.
1894. ‡Bisset, James, F.R.S.E. 9 Greenhill-park, Edinburgh.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Colonel W. H. 246 Belvidere-avenue, Detroit, Michigan, U.S.A.
1901. ‡Black, John Albert. Lagarie-row, Helensburgh, N.B.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.

Year of Election.

1901. §Black, W. P. M. 136 Wellington-street, Glasgow.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1900. ‡Blackburn, W. Owen. 3 Mount Royd, Bradford.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. (Local Sec. 1876). 1 Belhaven-terrace, Kelvinside, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1903. *Blackman, F. F., M.A., D.Sc. St. John's College, Cambridge.
1896. ‡*Blackwood, J. M. 16 Oil-street, Liverpool.*
1886. ‡Blaikie, John, F.L.S. The Bridge House, Newcastle, Staffordshire.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1883. *Blake, Rev. J. F., M.A., F.G.S. 35 Harlesden-gardens, N.W.
1902. ‡Blake, Robert F., F.I.C. 66 Malone-avenue, Belfast.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1881. ‡Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. ‡Blamires, William. Oak House, Taylor Hill, Huddersfield.
1904. §Blanc, Dr. Gian Alberto. Istituto Fisico, Rome.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., C.I.E., LL.D., F.R.S., F.G.S., F.R.G.S. (Pres. C, 1884; Council 1885–91.) 72 Bedford-gardens, Campden Hill, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., M.A., B.Sc. The University, Glasgow.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1902. ‡Blount, Bertram, F.I.C. 76 & 78 York-street, Westminster, S.W.
1888. ‡Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1901. §Blythswood, The Right Hon. Lord, LL.D. Blythswood, Renfrew.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. ‡Bodington, Principal N., Litt.D. Yorkshire College, Leeds.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 53 Victoria-street, S.W.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1900. ‡Boileau, Lieut.-Colonel A. C. T., R.A. Royal Artillery Institution, Woolwich.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §Bolton, H., F.R.S.E. The Museum, Queen's-road, Bristol.
1894. §Bolton, John. 15 Cranley-gardens, Highgate, N.
1898. ‡Bolton, J. W. Baldwin-street, Bristol.
1898. *Bonar, James, M.A., LL.D. (Pres. F, 1898; Council 1899– .) Civil Service Commission, Burlington-gardens, W.

Year of Election.

1883. ‡Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S. (Secretary, 1881–85; Pres. C, 1886.) 23 Denning-road, Hampstead, N.W.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Right Hon. Charles, D.Sc., F.R.S., F.S.S. 24 Great Cumberland-place, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1876. ‡Booth, Rev. William H. St. Paul's Rectory, Old Charlton, Kent.
1883. ‡Boothroyd, Benjamin. Weston-super-Mare.
1901. *Boothroyd, Herbert E., M.A., B.Sc. Sidney Sussex College, Cambridge.
1900. ‡*Borchgrevink, C. E. Lindfield, Sussex.*
1882. §Borns, Henry, Ph.D., F.C.S. 5 Sutton Court-road, Chiswick, W.
1901. ‡Borradaile, L. A., M.A. Selwyn College, Cambridge.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Teneriffe.
1903. §Bosanquet, Robert C. Rock Hall, Alnwick.
1896. ‡Bose, Professor J. C., C.I.E., M.A., D.Sc. Calcutta, India.
1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Tanglewood, Southside, Weston-super-Mare.
1887. ‡*Bott, Dr. Owens College, Manchester.*
1872. ‡Bottle, Alexander. 4 Godwyne-road, Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany in King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. ‡Boulnois, Henry Percy, M.Inst.C.E. 44 Campden House Court, Kensington, W.
1903. §Boulton, W. S. 2 Kymin-terrace, Penarth.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, S.W.
1883. ‡Bourne, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. *Bourne, G. C., M.A., D.Sc., F.L.S. (Council, 1903– ; Local Sec. 1894.) Savile House, Mansfield-road, Oxford.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1904. *Bousfield, E. G. P. Hungate Mills, York.
1902. ‡Bousfield, William. 20 Hyde Park-gate, W.
1898. ‡Bovey, Edward P., jun. Clifton-grove, Torquay.
1884. ‡Bovey, Henry T., M.A., F.R.S., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *Bower, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898; Council 1900–), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Seal, Sevenoaks.
1856. **Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.*
1898. §Bowley, A. L., M.A. Lynwood, Southern Hill, Reading.

Year of Election.

1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1899. *Bowman, Herbert Lister, M.A. Greenham Common, Newbury.
1899. *Bowman, John Herbert. Greenham Common, Newbury.
1887. ‡Box, Alfred Marshall. Care of Messrs. Cooper, Box, & Co., 69 Aldermanbury, E.C.
1895. *BOYCE, RUBERT, M.B., F.R.S., Professor of Pathology in the University of Liverpool.
1901. ‡Boyd, David T. Rhinsdale, Ballieston, Lanark.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1884. *Boyle, R. Vicars, C.S.I. 3 Stanhope-terrace, Hyde Park, W.
1892. §BOYS, CHARLES VERNON, F.R.S. (Pres. A, 1903; Council, 1893–99.) 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. (Pres. H, 1898; Pres. F, 1903; Council, 1903–). 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Ingleside, Malvern Wells.
1904. *Bradley, Gustav. Town Hall, Barrow-in-Furness.
1899. *Bradley, J. W., Assoc.M.Inst.C.E., F.G.S. Westminster City Hall, Charing Cross-road, W.C.
1903. *Bradley, O. Charnock, M.B., F.R.S.E. Royal Veterinary College, Edinburgh.
1892. ‡Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1898. ‡Bramble, Lieut.-Colonel James R., F.S.A. Seafield, Weston-super-Mare.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. 72 Hills-road, Cambridge.
1885. *Bratby, William, J.P. Alton Lodge, Hale, Bowdon, Cheshire.
1902. ‡Braun, Henry C. 1 North-street, King's Cross, N.
1890. *Bray, George. Belmont, Wood-lane, Headingley, Leeds.
1902. *Brereton, Cloudesley. Briningham House, Briningham, S.O., Norfolk.
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. *Bretherton, C. E. 12 The Paragon, Blackheath, S.E.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡*Brice, Arthur Montefiore, F.G.S., F.R.G.S.* 28 *Addison-mansions, Kensington, W.*
1886. §BRIDGE, T. W., M.A., D.Sc., F.R.S., Professor of Zoology in the University of Birmingham.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1904. *Briggs, William, M.A., LL.D., F.R.A.S. University Tutorial Press, Burlington House, Cambridge.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡*Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, S.W.*

Year of
Election.

1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. Municipal Technical Institute, Romford-road, West Ham, E.
1904. §Briscoe, B. H. Bourn Hall, Bourn, Cambridgeshire.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1898. ‡Bristol, The Right Rev. G. F. Browne, D.D., Lord Bishop of. 17 The Avenue, Clifton, Bristol.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1899. ‡Broadwood, Miss Bertha M. Pleystowe, Capel, Surrey.
1899. ‡Broadwood, James H. E. Pleystowe, Capel, Surrey.
1897. ‡Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1883. *Brodie, David, M.D. Slingsby Villa, Regent's Park-road, N.
1901. §Brodie, T. G., M.D., F.R.S. 4 Lancaster-terrace, Regent's Park, N.W.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1901. ‡Brodie, W. Brodie, M.D., F.R.S.E. 28 Hamilton Park-terrace, Hillhead, Glasgow.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1903. ‡Brodrick, Harold, M.A. (Local Sec., 1903.) 7 Aughton-road, Birkdale, Southport.
1904. §Bromich, T. J. I'A., M.A., Professor of Mathematics in Queen's College, Galway.
1881. ‡Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1883. *Brotherton, E. A., M.P. Arthington Hall, Wharfedale, viâ Leeds.
1901. §Brough, Bennett H., F.I.C., F.G.S. 28 Victoria-street, S.W.
1883. *Brough, Mrs. Charles S. Frankville, Eastern Villas-road, Southsea.
1886. ‡Brough, Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwyth.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871), Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1896. ‡Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Sir Charles Gage, M.D., K.C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1903. ‡Brown, F. W. 6 Rawlinson-road, Southport.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1807. §Brown, Horace T., LL.D., F.R.S., F.G.S. (Pres. B, 1899; Council, 1904– .) 52 Nevern-square, S.W.

Year of Election.

1870. *Brown, J. Campbell, D.Sc., F.C.S., Professor of Chemistry in the University of Liverpool.
1876. §Brown, John, F.R.S. (Local Sec. 1902.) Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. c/o James Dick, Esq., St. Thomas-road, Beven, Durban, Natal.
1882. **Brown, John. 7 Second-avenue, Nottingham.*
1895. *Brown, John Charles. Burlington-road, Sherwood, Nottingham.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. *Brown, Mrs. Mary. c/o James Dick, Esq., St Thomas-road, Beven, Durban, Natal.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1897. ‡Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. ‡Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897. ‡Brown, Richard. Jarvis-street, Toronto, Canada.
1901. ‡Brown, R. N. R., B.Sc. University College, Dundee.
1896. ‡Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §Brown, T. Forster, M.Inst.C.E. (Pres. G, 1891.) Springfort, Stoke Bishop, Bristol.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1900. *Browne, Frank Balfour. The Cottage, Catfield, Great Yarmouth.
1895. *Browne, H. T. Doughty. 10 Hyde Park-terrace, W.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891. ‡Browne, Montagu, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. ‡Browning, John, F.R.A.S. 78 Strand, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1901. ‡Bruce, John. Inverallan, Helensburgh.
1893. ‡Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1902. ‡*Bruce-Kingsmill, Captain J., R.A. Royal Arsenal, Woolwich.*
1900. *Brumm, Charles. Lismara, Grosvenor-road, Birkdale, Southport.
1875. ‡Brunlees, John, M.Inst.C.E. 12 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡Brunton, Sir T. Lauder, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. ‡Brutton, Joseph. Yeovil.
1886. *Bryan, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. ‡Bryce, Rev. Professor George. Winnipeg, Canada.
1897. ‡Bryce, Right Hon. James, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1901. §Bryce, Thomas H. 2 Granby-terrace, Hillhead, Glasgow.
1894. ‡Brydone, R. M. Petworth, Sussex.
1902. *Bubb, Miss E. Maude. Ullenwood, near Cheltenham.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §Buchan, Alexander, M.A., LL.D., F.R.S., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.

Year of Election.

1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1902. *Buchanan, Miss Florence, D.Sc. University Museum, Oxford.
1901. ‡Buchanan, James, M.D. 12 Hamilton-drive, Maxwell Park, Glasgow.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. Christ's College, Cambridge.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1904. §Buckwell, J. C. Northgate House, Pavilion, Brighton.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1893. §BULLEID, ARTHUR, F.S.A. The Old Vicarage, Midsomer Norton, Bath.
1903. *Bullen, Rev. R. Ashington. Pyrford Vicarage, Woking, Surrey.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1883. ‡Bulpit, Rev. W. T. Crossens Rectory, Southport.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1899. ‡Burls, Herbert T. Care of Messrs. H. S. King & Co., Cornhill, E.C.
1904. §Burn, R. H. 21 Stanley-crescent, Notting Hill, W.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.I.E., K.C.S.I., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. Migvie House, North Silver-street, Aberdeen.
1877. ‡Burns, David. Vallum View, Burgh-road, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1899. ‡Burr, Malcolm. Dorman's Park, East Grinstead.
1860. ‡Burrows, Montagu, M.A. Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, Sir John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Lady. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1897. ‡Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union-crescent, Margate.
1904. §Burtt, Arthur H., D. Sc. 4 South View, Holgate, York.

Year of Election.

1897. ‡Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. ‡Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1884. *Butterworth, W. Park-avenue, Temperley, near Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1881. ‡Buxton, Sydney C., M.P. 15 Eaton-place, S.W.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir Thomas Fowell, Bart., G.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1899. §Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. The Rowans, Fairfield, near Manchester.

1889. ‡*Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.*
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Roseangle, Dundee.
1901. ‡Caldwell, Hugh. Blackwood, Newport, Monmouthshire.
1868. ‡Caley, A. J. Norwich.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 16 Montpellier-villas, Cheltenham.
1897. §CALLENDAR, HUGH L., M.A., LL.D., F.R.S. (Council, 1900–), Professor of Physics in the Royal College of Science. 2 Chester-place, Regent's Park, N.W.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
1901. ‡Calvert, H. T. Roscoe-terrace, Armley, Leeds.
1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 15 Pembroke-road, Dublin.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1901. §Campbell, Archibald. Park Lodge, Albert-drive, Pollokshields, Glasgow.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, Right Hon. James A., LL.D., M.P. Stracathro House, Brechin.
1897. ‡Campbell, Colonel J. C. L. Achalader, Blairgowrie, N.B.
1901. ‡Campbell, M. Pearce. 9 Lynedoch-crescent, Glasgow.
1902. ‡Campbell, Robert. 21 Great Victoria-street, Belfast.
1897. ‡Campion, B. W. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡CANNAN, EDWIN, M.A., LL.D., F.S.S. (Pres. F, 1902.) 46 Wellington-square, Oxford.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1904. §Capell, Rev. G. M. Passenham Rectory, Stony Stratford.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, W.
1894. §CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1887. ‡CAPSTICK, JOHN WALTON. Trinity College, Cambridge.

Year of Election.

1873. *Carbutt, Sir Edward Hamer, Bart., M.Inst.C.E. 19 Hyde Park-gardens, W.
1896. *Carden, H. Vandeleur. Fassaroe, Walmer.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1898. ‡Carlile, George M. 7 Upper Belgrave-road, Bristol.
1901. ‡Carlile, W. Warrand. Harlie, Largs, Ayrshire.
1867. ‡Carmichael, David (Engineer). Dundee.
1876. ‡Carmichael, Niel, M.D. 177 Nitherdale-road, Pollokshields, Glasgow.
1897. ‡Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1902. ‡Carpenter, G. H., B.Sc. Science and Art Museum, Dublin.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897. †Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡Carruthers, William, F.R.S., F.L.S., F.G.S. (Pres. D, 1886.) 14 Vermont-road, Norwood, S.E.
1886. ‡Carslake, J. Barham (Local Sec. 1886). 30 Westfield-road, Birmingham.
1899. ‡Carslaw, H. S., D.Sc., Professor of Mathematics in the University of Sydney, N.S.W.
1883. ‡Carson, John. 41 Royal-avenue, Belfast.
1903. *Cart, Rev. Henry. 49 Albert-court, Kensington Gore, S.W.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1866. ‡*Carter, H. H. The Park, Nottingham.*
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1900. *Carter, Rev. W. Lower, M.A., F.G.S. Hopton, Mirfield, Yorkshire.
1896. ‡Cartwright, Miss Edith G. 21 York Street-chambers, Bryanston-square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Myskyns, Ticehurst, Sussex.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I. Peel-chambers, Market-place, Bury, Lancashire.
1862. †Carulla, F. J. R. 84 Rosehill-street, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, S.W.
1901. ‡Carver, Thomas A. B., B.Sc., Assoc. M.Inst.C.E. 118 Napiershall-street, Glasgow.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1899. **Case, J. Monckton. Hampden Club, Phœnix-street, N.W.*
1897. *Case, Willard E. Auburn, New York, U.S.A.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1904. §Caspair, W. A. National Physical Laboratory, Bushy House, Teddington, Middlesex.
1900. *Cassie, W., M.A., Professor of Physics in the Royal Holloway College. Brantwood, Englefield Green.
1897. †Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.

Year of Election.

1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyle, Mrs. Isabella. St. Paul's Vicarage, Cheltenham.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1901. §Chamen, W. A. 75 Waterloo-street, Glasgow.
1881. *Champney, John E. 27 Hans-place, S.W.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1902. §Chapman, D. L. 10 Parsonage-road, Withington, Manchester.
1861. *Chapman, Edward, M.A., M.P., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1897. ‡Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1899. §Chapman, Professor Sydney John, M.A. Victoria University, Manchester.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1904. §CHASE, Rev. F. H., D.D. Queen's College, Cambridge.
1903. ‡Chaster, G. W. 42 Talbot-road, Southport.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1904. *Chattaway, F. D. Longfield, Kenton-road, Harrow.
1884. *CHATTERTON, GEORGE, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *CHATTOCK, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1904. *Chaundy, Theodore William. 49 Broad-street, Oxford.
1884. ‡CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 19 Portman-street, Portman-square, W.
1900. §Cheesman, W. Norwood. The Crescent, Selby.
1887. ‡*Cheetham, F. W. Limefield House, Hyde.*
1887. ‡*Cheetham, John. Limefield House, Hyde.*
1896. ‡Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡*Cherriman, Professor J. B. Ottawa, Canada.*
1896. ‡Cherry, R. B. 92 Stephen's-green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. ‡CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. 59 Drakefield-road, Upper Tooting, S.W.
1900. ‡CHISHOLM, Sir SAMUEL. Glasgow.
1899. §Chitty, Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, Mrs. Edward. Sonnenberg, Castle-avenue, Dover.
1899. §Chitty, G. W. Brockhill Park, Hythe, Kent.
1904. §Chivers, John, J.P. Histon, Cambridgeshire.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡*Chorlton, J. Clayton. New Holme, Withington, Manchester.*

Year of Election.

1893. *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke Street, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Common, S.W.
1876. *CHRYSTAL, GEORGE, M.A., LL.D., F.R.S.E. (Pres. A, 1885), Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §CHURCH, Colonel G. EARL, F.R.G.S. (Pres. E, 1898.) 216 Cromwell-road, S.W.
1860. ‡CHURCH, Sir WILLIAM SELBY, Bart., M.D., D.Sc. St. Bartholomew's Hospital, E.C.
1896. ‡Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1903. §Clapham, J. H., M.A., Professor of Economics in the University of Leeds.
1901. §Clark, Archibald B., M.A. 16 Comely Bank-street, Edinburgh.
1876. ‡Clark, David R., M.A. 8 Park-drive West, Glasgow.
1890. ‡*Clark, E. K.* 13 *Wellclose-place, Leeds.*
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
1902. ‡Clark, G. M. Cape Town.
1892. ‡Clark, James. Chapel House, Paisley.
1901. ‡Clark, James M., M.A., B.Sc. 8 Park-drive West, Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc. Lilegarth, Ashburton-road, Croydon.
1901. *Clark, Robert M., B.Sc., F.L.S. 27 Albyn-place, Aberdeen.
1855. ‡Clark, Rev. William, M.A. Beechcroft, Jordan-hill, Glasgow.
1887. ‡Clarke, C. Goddard, J.P. South Lodge, Champion-hill, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1875. ‡CLARKE, JOHN HENRY. (Local Sec. 1875.) 4 Worcester-terrace, Clifton, Bristol.
1902. §Clarke, Miss Lilian J., B.Sc. 81 Hornsey Rise, N.
1897. ‡*Clarke, Colonel S. C., R.E. Parklands, Caversham, near Reading.*
1896. ‡Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. *CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1861. ‡CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1902. §Clements, Olaf P. Tana, St. Bernard's-road, Olton, Warwick.
1904. §Clerk, Dugald, M.Inst.C.E. 18 Southampton-buildings, W.C.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1898. ‡Clissold, H. 30 College-road, Clifton, Bristol.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893.) The Grange, College-road, Dulwich, S.E.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
1897. ‡Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
1903. *Coates, W. M. Queen's College, Cambridge.
1901. ‡Coats, Allan. Hayfield, Paisley.
1884. §Cobb, John. Fitzherries, Abingdon.

Year of Election.

1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡*Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.*
1901. ‡Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone-road, Upper Norwood, S.E.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. 26 Belgrave-road, Eccleston-square, S.W.
1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1901. §Cohen, N. L. 11 Hyde Park-terrace, W.
1901. *Cohen, R. Waley, B.A. 11 Hyde Park-terrace, W.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby William Henry. Carregwen, Aberystwyth.
1893. ‡Cole, Professor Grenville A. J., F.G.S. Royal College of Science, Dublin.
1903. ‡Cole, Otto B. 551 Boylston-street, Boston, U.S.A.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1864. ‡*Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, S.W.*
1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1899. §Coleman, William. The Shrubbery, Buckland, Dover.
1878. ‡Coles, John, F.R.G.S. Liphook, Hants.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1899. §Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. ‡Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Organic Chemistry in the University of London. 16 Campden-grove, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. ‡Collinge, Walter E. The University, Birmingham.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. ‡COLLINS, J. H., F.G.S. 162 Barry-road, S.E.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1902. ‡Collins, T. R. Belfast Royal Academy, Belfast.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Right Hon. Sir J. C. R., K.C.M.G., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. ‡Colquhoun, A. H. U., B.A. 39 Borden-street, Toronto, Canada.
1888. †Commans, R. D. Macaulay-buildings, Bath.
1891. ‡*Common, J. F. F. 21 Park-place, Cardiff.*
1900. ‡Common, T. A., B.A. 63 Eaton-rise, Ealing, W.
1892. ‡Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1902. ‡Conway, A. W. 100 Leinster-road, Rathmines, Dublin.

Year of Election.

1893. ‡CONWAY, Professor Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, W.
1903. §Conway, R. Seymour, Litt.D., Professor of Latin in Owens College, Manchester.
1899. ‡COODE, J. CHARLES, M.Inst.C.E. Westminster-chambers, 9 Victoria-street, S.W.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1900. ‡Cook, Walter. 98 St. Mary's-street, Cardiff.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1868. ‡COOKE, M. C., M.A. 53 Castle-road, Kentish Town, N.W.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1881. ‡Cooke, Thomas. Bishopshill, York.
1896. ‡Cookson, E. H. Kiln Hey, West Derby.
1899 *Coomáraswámy, A. K., B.Sc., F.L.S., F.G.S., Director of the Mineral Survey of Ceylon. Kandy, Ceylon.
1902. *Coomáraswámy, Mrs. A. K. Kandy, Ceylon.
1903. §Cooper, Miss A. J. 22 St. John-street, Oxford.
1895. ‡*Cooper, Charles Friend, M.I.E.E.* 68 *Victoria-street, Westminster, S.W.*
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1893. ‡*Cooper, F. W.* 14 *Hamilton-road, Sherwood Rise, Nottingham.*
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡COPELAND, RALPH, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1904. *COPEMAN, S. MONCKTON, M.D., F.R.S. Local Government Board, Whitehall, S.W.
1904. *Copland, Miss Louisa. 14 Brunswick-gardens, Kensington, W.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1901. §Corbett, A. Cameron, M.P. Thornliebank House, Glasgow.
1891. ‡Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. Fairlight, 22 Oliver-grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Groombridge House, Withington, Manchester.
1901. *Cormack, Professor J. D., B.Sc. University College, Gower-street, W.C.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡CORNISH, VAUGHAN, D.Sc., F.R.G.S. 72 Prince's-square, W.
1884. *Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Park Hill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., F.R.A.S. Stonyhurst College, Blackburn.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1891. **Cotsworth, Haldane Gwilt. The Cedars, Cobham-road, Norbiton, S.W.*
1874. *COTTERILL, J. H., M.A., F.R.S. Braeside, Speldhurst, Kent.
1904. §Coulter, G. G. 28 Pall Mall, S.W.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1896. ‡COURTNEY, Right Hon. LEONARD (Pres. F, 1896). 15 Cheyne-walk, Chelsea, S.W.

Year of Election.

1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. ‡Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 10 Buckingham-street, Strand, W.C.
1903. ‡Coward, H. Knowle Board School, Bristol.
1900. §Cowburn, Henry. Dingle Head, Westleigh, Leigh, Lancashire.
1895. *Cowell, Philip H., M.A. Royal Observatory, Greenwich, and 74 Vanbrugh-park, Blackheath, S.E.
1899. ‡Cowper-Coles, Sherard. 82 Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway, Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1890. ‡Cradock, George. Wakefield.
1902. ‡Craig, H. C. Strandtown, Belfast.
1884. §Craigie, Major P. G., C.B., F.S.S. (Pres. F, 1900.) Board of Agriculture and Fisheries, 3 St. James's-square, S.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. ‡*Craven, John. Smedley Lodge, Cheetham, Manchester.*
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton-road, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. 2 Cavendish-square, W.; and Haigh Hall, Wigan.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §Creak, Captain E. W., C.B., R.N., F.R.S. (Pres. E., 1903; Council 1896–1903.) 9 Hervey-road, Blackheath, S.E.
1901. ‡Cree, T. S. 15 Montgomerie-quadrant, Glasgow.
1896. ‡Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. ‡Crichton, Hugh. 6 Rockfield-road, Anfield, Liverpool.
1904. §Crilly, David. 7 Well-street, Paisley.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, Co. Limerick.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, J. W., M.A., M.P. (Local Sec. 1885). Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1903. *Crompton, Holland. Binfield, Northwood, Middlesex.
1901. ‡Crompton, Colonel R. E., C.B., M.Inst.C.E. (Pres. G, 1901.) Kensington Court, W.
1887. §Crook, Henry T., M.Inst.C.E. 9 Albert-square, Manchester.

Year of Election.

1898. §Crooke, William. Langton House, Charlton Kings, Cheltenham.
1865. §CROOKES, Sir WILLIAM, D.Sc., F.R.S., V.P.C.S. (PRESIDENT, 1898; Pres. B, 1886; Council 1885–91). 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M.B. Ashdown Forest, Forest Row, Sussex.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. 3 Fulwood-park, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1904. §Cross, Professor Charles R. Massachusetts Institute of Technology, Boston, U.S.A.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1904. *CROSSLEY, A. W., D.Sc., Ph.D., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 7A Crediton-road, West Hampstead, N.W.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham-lane, Bradford.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1898. ‡CRUNDALL, Sir WILLIAM H. Dover.
1888. ‡Culley, Robert. Bank of Ireland, Dublin.
1883. *CULVERWELL, EDWARD P., M.A. 40 Trinity College, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1897. ‡Cumberland, Barlow. Toronto, Canada.
1898. §Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E. (Pres. H, 1901; Council, 1902–), Professor of Anatomy in the University of Edinburgh.
1891. ‡Cunningham, J. H. 2 Ravelston-place, Edinburgh.
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. W., D.D., D.Sc. (Pres. F, 1891). Trinity College, Cambridge.
1892. §Cunningham-Craig, E. H., B.A., F.G.S. 14A Dublin-street, Edinburgh.
1900. *Cunnington, W. Alfred. 13 The Chase, Clapham Common, S.W.
1892. *Currie, James, jun., M.A., F.R.S.E. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1902. §Curry, Professor M., M.Inst.C.E. 5 King's-gardens, Hove.
1898. ‡Curtis, John. 1 Christchurch-road, Clifton, Bristol.

Year of Election.

1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, S.W.

1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1898. §Dalby, W. E., D.Sc., M.Inst.C.E., Professor of Civil and Mechanical Engineering in the City and Guilds of London Institute, Exhibition-road, S.W. 45 Clifton-road, Crouch End, N.
1889. *Dale, Miss Elizabeth. 45 Oxford-road, Cambridge.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1870. ‡DALLINGER, Rev. W. H., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
1904. *DALTON, J. H. C., M.D. The Plot, Adams-road, Cambridge.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1901. ‡Daniell, G. F., B.Sc. 44 Cavendish-road, Brondesbury, N.W.
1876. *Dansken, John, F.R.A.S. 2 Hillside-gardens, Partickhill, Glasgow.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, W.
1897. ‡Darbishire, C. W. Elm Lodge, Elm-row, Hampstead, N.W.
1897. §Darbishire, F. V., B.A., Ph.D. Hulme Hall, Plymouth-grove, and Owens College, Manchester.
1903. §Darbishire, Dr. Otto V. Owens College, Manchester.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. (Local Sec. 1861.) Victoria Park, Manchester.
1896. ‡Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1904. *Darwin, Charles Galton. Newnham Grange, Cambridge.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. (Pres. D, 1891; Pres. K, 1904; Council 1882-84, 1897-1901). 30 Kensington-square, W.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S. (PRESIDENT ELECT; Pres. A, 1886; Council 1886-92), Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *DARWIN, HORACE, M.A., F.R.S. The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, Hon. Sec. R.G.S. (Pres. E, 1896; Council 1899-). 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1898. §Davey, William John. 6 Water-street, Liverpool.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1904. §Davidge, H. T., B.Sc., Professor of Electricity in the Ordnance College, Woolwich.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1902. *Davidson, S. C. Seacourt, Bangor, Co. Down.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1904. §Davies, Henry N. St. Chad's, Weston-super-Mare.

Year of Election.

1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1893. *Davies, Rev. T. Witton, B.A., Ph.D., Professor of Semitic Languages in University College, Bangor, North Wales.
1898. ‡Davies, Wm. Howell, J.P. Down House, Stoke Bishop, Bristol.
1873. *Davis, Alfred. 37 Ladbroke-grove, W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. Valindra, Wood Green, Wednesbury, Staffordshire.
1885. *Davis, Rev. Rudolf. Hopefield, Evesham.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡Davison, Charles, D.Sc. 16 Manor-road, Birmingham.
1857. ‡Davy, E. W., M.D. Kimmage Lodge, Roundtown, Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡Dawkins, W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council, 1882–88), Professor of Geology and Palæontology in the University of Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. **Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.*
1901. *Dawson, P. The Acre, Maryhill, Glasgow.
1884. ‡Dawson, Samuel (Local Sec. 1884). 258 University-street, Montreal, Canada.
1859. **Dawson, Captain William G. The Links, Plumstead Common, Kent.*
1892. ‡Day, T. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *Deacon, G. F., LL.D., M.Inst.C.E. (Pres. G, 1897.) 19 Warwick-square, S.W.
1900. §Deacon, M. Whittington House, near Chesterfield.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1901. *Deasy, Capt. H. H. P. Cavalry Club, Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. (Pres. B, 1869; Council, 1870–75). 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. ‡Deeley, R. M. 38 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. University College, Dublin.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1902. ‡Dendy, Professor Arthur. Care of Messrs. Dulau & Co., 37 Soho-square, W.
1897. ‡Denison, F. Napier. Meteorological Office, Victoria, B.C., Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889. §Denny, Alfred, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, W.
1874. ‡De Rance, Charles E., F.G.S. 33 Carshalton-road, Blackpool.
1896. ‡Derby, The Right Hon. the Earl of, K.G., G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1903. §Devereux, Rev. E. R. Price. Drachenfeld, Tenison-avenue, Cambridge.

Year of Election.

1899. ‡DEVONSHIRE, The Duke of, K.G., D.C.L., F.R.S. Devonshire House, Piccadilly, W.

1899. ‡*Dewar, A. Redcote. Redcote, Leven, Fife.*

1868. *DEWAR, SIR JAMES, M.A., LL.D., D.Sc., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. (PRESIDENT, 1902; Pres. B, 1879; Council 1883–88.) 1 Scroope-terrace, Cambridge.

1881. ‡Dewar, Lady. 1 Scroope-terrace, Cambridge.

1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.

1884. *Dewar, William, M.A. Horton House, Rugby.

1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, W.

1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.

1896. ‡*D'Henry, P. 136 Prince's-road, Liverpool.*

1897. ‡Dick, D. B. Toronto, Canada.

1901. §Dick, George Handasyde. 31 Hamilton-drive, Hillhead, Glasgow.

1901. ‡Dick, Thomas. Lochhead House, Pollokshields, Glasgow.

1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.

1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.

1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.

1904. §Dickson, Charles Scott, K.C., LL.D., M.P., Lord Advocate for Scotland. Scottish Office, Whitehall, S.W.

1881. ‡Dickson, Edmund, M.A., F.G.S. 2 Starkie-street, Preston.

1887. §DICKSON, H. N., B.Sc., F.R.S.E., F.R.G.S. 2 St. Margaret's-road, Oxford.

1902. §Dickson, James D. Hamilton, M.A., F.R.S.E. 6 Cranmer-road, Cambridge.

1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.

1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.

1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.

1901. §Dines, W. H. Oxshott, Leatherhead.

1900. §DIVERS, Dr. EDWARD, F.R.S. (Pres. B, 1902.) 3 Canning-place, Palace Gate, W.

1898. *Dix, John William S. Hampton Lodge, Durdham Down, Clifton, Bristol.

1899 *DIXON, A. C., D.Sc., F.R.S. Professor of Mathematics in Queen's College, Belfast. Almora, Myrtlefield Park, Belfast.

1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.

1900. ‡Dixon, A. Francis, Sc.D., Professor of Anatomy in the University of Dublin.

1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.

1888. §Dixon, Edward T. Racketts, Hythe, Hampshire.

1900. *Dixon, George, M.A. St. Bees, Cumberland.

1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894), Professor of Chemistry in the Victoria University, Manchester.

1902. ‡Dixon, Henry H., D.Sc. 23 Northbrook-road, Dublin.

1885. ‡Dixon, John Henry. Dundarach, Pitlochry, N.B.

1896. §Dixon-Nuttall, F. R. Ingleholme, Eccleston Park, Prescot.

1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.

1902. ‡Dixon, W. V. Scotch Quarter, Carrickfergus.

1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.

1890. ‡Dobbie, James J., D.Sc., F.R.S., Director of the Museum of Science and Art, Edinburgh.

Year of Election.

1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Fylde Cottage, Branksome-avenue, Bournemouth.
1902. ‡Dobbs, F. W. 2 Willowbrook, Eton, Windsor.
1897. ‡Doberck, William. The Observatory, Hong Kong.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897. ‡Dodge, Richard E. Teachers' College, Columbia University, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1898. ‡*Dole, James. Redland House, Bristol.*
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. †Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1904. §Doncaster, Leonard. King's College, Cambridge.
1889. ‡*Donkin, R. S., M.P. Campville, North Shields.*
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. ‡Donnan, F. G. University College, Gower Street, W.C.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Illawara House, Tunbridge Wells.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. Wycombe Abbey School, Buckinghamshire.
1903. §Dow, Miss Agnes R. Flat 1, 27 Warrington-crescent, W.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1884. *Dowling, D. J. Sycamore, Clive-avenue, Hastings.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. Merry Hall, Ashtead, Surrey.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. ‡Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡Dresser, Henry E., F.Z.S. 110 Cannon-street, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1893. §Druce, G. Claridge, M.A., F.L.S. (Local Sec. 1894.) 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1897. ‡Drynan, Miss. Northwold, Queen's Park, Toronto, Canada.
1901. ‡Drysdale, John W. W. Bon Accord Engine Works, London-road, Glasgow.
1892. ‡*Du Bois, Dr. H. Mittelstrasse 39, Berlin.*
1856. *Ducie, The Right. Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 7 Grey Friars, Chester.
1900. *Duckworth, W. L. H., M.A. Jesus College, Cambridge.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *Duff, The Right Hon. Sir Mountstuart Elphinstone Grant-, G.C.S.I., F.R.S., F.R.G.S. (Pres. F, 1867, 1881; Council 1868, 1892–93.) 11 Chelsea-embankment, S.W.
1904. §Duffield, W. G. 5 Bridge-approach, Teddington, Middlesex.
1875. ‡Duffin, W. E. L'Estrange. Waterford.

Year of Election.

1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1892. ‡*Dulier, Colonel E., C.B.* 27 *Sloane-gardens, S.W.*
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1896. ‡Duncanson, Thomas. 16 Deane-road, Liverpool.
1893. *Dunell, George Robert. 33 Spencer-road, Grove Park, Chiswick, W.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1896. *DUNKERLEY, S., M.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. ‡Dunnachie, James. 48 West Regent-street, Glasgow.
1884. §Dunnington, Professor F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R., Principal of the South-Eastern Agricultural College, Wye, Kent.
1891. ‡Dunstan, Mrs. South-Eastern Agricultural College, Wye, Kent.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M. Newport House, near Exeter.
1898. ‡Durrant, R. G. Marlborough College, Wilts.
1895. *DWERRYHOUSE, ARTHUR R., M.Sc., F.G.S. 5 Oakfield-terrace, Headingley, Leeds.
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1895. §Dymond, Thomas S., F.C.S. County Technical Laboratory, Chelmsford, Essex.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. ‡Earle, Hardman A. Salford Iron Works, Manchester.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1899. §East, W. H. Municipal School of Art, Science, and Technology, Dover.
1871. *EASTON, EDWARD. (Pres. G, 1878; Council 1879–81.) 7 Victoria-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1903. §Eccles, W. H., D.Sc. 1 Owen's-mansions, Queen's Club-gardens, West Kensington, W.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1899. ‡Eddowes, Alfred, M.D. 28 Wimpole-street, W.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. Sywell House, Llandudno.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council 1879–86, 1891–98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.

Year of
Election.

1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 4 Chichester-terrace, Kemp Town, Brighton.
1883. ‡Edmunds, Lewis, D.Sc., LL.M., F.G.S. 1 Garden-court, Temple, E.C.
1901. *EDRIDGE-GREEN, F. W., M.D., F.R.C.S. St. John's College, Cambridge.
1899. §Edwards, E. J., Assoc.M.Inst.C.E. 232 Trinity-road, Wandsworth, S.W.
1903. ‡Edwards, Mrs. Emily. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Francis. Norley Grange, 73 Leyland-road, Southport.
1903. ‡Edwards, Miss Marion K. Norley Grange, 73 Leyland-road, Southport.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1901. ‡Eggar, W. D. Willowbrook, Eton, Windsor.
1896. ‡Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 34 Leadenhall-street, E.C.
1904. §Eliot, Sir John, K.C.I.E., M.A., F.R.S. 54 Prince of Wales-mansions, Battersea Park, S.W.
1901. *Elles, Miss Gertrude L. Newnham College, Cambridge.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1904. §Elliot, R. H. Clifton Park, Kelso, N.B.
1904. §Elliot, T. R. B. Holme Park, Rotherfield, Sussex.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1904. §Elliott, Miss Agnes I. M. Newnham College, Cambridge.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡ELLIOT, Sir THOMAS HENRY, K.C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY (Local Sec. 1883.) 3 Carlisle-terrace, The Hoe, Plymouth.
1891. §Ellis, Miss M. A. 129 Walton-street, Oxford.
1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, Toronto, Canada.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, W.C.
1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
1883. ‡Elwes, Captain George Robert. Bossington, Bournemouth.
1887. §ELWORTHY, FREDERICK T., F.S.A. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1897. ‡Ely, Robert E. 23 West 44th-street, New York, U.S.A.
1891. ‡Emerton, Wolseley, D.C.L. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.

Year of Election.

1894. ‡Emtage, W. T. A., Director of Public Instruction, Mauritius.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894. ‡Erskine-Murray, James, D.Sc., F.R.S.E. University College, Nottingham.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles. 5 Seymour-grove, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 5 Seymour-grove, Old Trafford, Manchester.
1901. ‡Ettersbank, John. Care of Messrs. Dalgety & Co., 52 Lombard-street, E.C.
1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.
1870. *EVANS, ARTHUR JOHN, M.A., F.R.S., F.S.A. (Pres. H, 1896.) Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. Parkstone, Dorset.
1896. ‡Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1887. *Evans, Mrs. Isabel. Hoghton Hall, Hoghton, near Preston.
1883. *Evans, Mrs. James C. 38 Crescent-road, Birkdale, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. (PRESIDENT, 1897; Pres. C, 1878; Pres. H, 1890; Council 1868-74, 1875-82, 1889-96.) Nash Mills, Hemel Hempstead.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1898. ‡Evans, Jonathan L. 4 Litfield-place, Clifton, Bristol.
1881. ‡Evans, Lewis. Llanfyrnach, R.S.O., Pembrokeshire.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Abbot's Barton, Canterbury.
1899. ‡Evans, Mrs. Abbot's Barton, Canterbury.
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡*Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.*
1903. ‡Evatt, E. J., M.B. 8 Kyveilog-street, Cardiff.
1871. ‡Eve, H. Weston, M.A. 37 Gordon-square, W.C.
1902. *Everett, Percy W. Oaklands, Elstree, Hertfordshire.
1895. ‡Everett, W. H., B.A. University College, Nottingham.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡EWART, Sir W. QUARTUS, Bart. (Local Sec. 1874.) Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., LL.D., F.R.S., F.R.S.E., M.Inst. C.E. Royal Naval College, Greenwich, S.E.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1903. §Ewing, Peter, F.L.S. The Frond, Uddingston, Glasgow.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. ‡Fairbrother, Thomas. 46 Lethbridge-road, Southport.
1901. §Fairgrieve, M. McCallum. 115 Dalkeith-road, Edinburgh.

Year of Election.

1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Cheshire.
1902. §Fallaize, E. N., M.A. 25 Alexandra-mansions, Middle-lane, Hornsey, N.
1898. §Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1877. §FARADAY, F. J., F.L.S., F.S.S. (Local Sec. 1887.) College-chambers, 17 Brazennose-street, Manchester.
1902. ‡Faren, William. 11 Mount Charles, Belfast.
1892. *FARMER, J. BRETLAND, M.A., F.R.S., F.L.S., Professor of Botany, Royal College of Science, Exhibition-road, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1904. §Farnworth, Miss Olive. Broadlands, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡FARQUHARSON, Colonel Sir J., K.C.B., R.E. Corrachee, Tarland, Aberdeen.
1885. *Farquharson, Mrs. R. F. O. Tillydrine, Kincardine O'Neil, N.B.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1904. §Farrer, Sir William. 18 Upper Brook-street, W.
1897. ‡Farthing, Rev. J. C., M.A. The Rectory, Woodstock, Ontario, Canada.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1903. §Faulkner, Joseph M. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1900. ‡FAWCETT, J. E., J.P. (Local Sec. 1900.) Low Royd, Apperley Bridge, Bradford.
1902. *Fawsitt, C. E., Ph.D. 9 Foremount-terrace, Dowanhill, Glasgow.
1901. *Fearnsides, W. G., B.A., F.G.S. Sidney Sussex College, Cambridge.
1886. ‡Felkin, Robert W., M.D., F.R.G.S. 48 Westbourne-gardens, Bayswater, W.
1900. *Fennell, William John. Deramore Drive, Belfast.
1904. §Fenton, H. J. H. 19 Brookside, Cambridge.
1883. ‡Fenwick, E. H. 29 Harley-street, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1902. ‡FERGUSON, GODFREY W. (Local Sec. 1902.) Cluan, Donegall Park, Belfast.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1896. *Ferguson, John. Colombo, Ceylon.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmonth-terrace, Edinburgh.
1901. ‡Ferguson, R. W. Municipal Technical School, The Gamble Institute, St. Helens, Lancashire.
1883. ‡Fernald, H. P. Clarence House, Promenade, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1873. ‡FERRIER, DAVID, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1892. ‡Ferrier, Robert M., B.Sc., Professor of Engineering, University College, Bristol.
1897. ‡Ferrier, W. F. Geological Survey, Ottawa, Canada.

Year of Election.

1897. ‡Fessenden, Reginald A., Professor of Electrical Engineering, University, Alleghany, Pennsylvania, U.S.A.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1897. ‡Field, George Wilton, Ph.D. Experimental Station, Kingston, Rhode Island, U.S.A.
1886. ‡*Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.*
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1904. *Findlay, J. J., Ph.D., Professor of Education in the University of Manchester.
1902. §Finnegan, J., B.A., B.Sc. Kelvin House, Botanic-avenue, Belfast.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 10 Albion-place, Doncaster.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1902. ‡Fisher, J. R. Cranfield, Fortwilliam Park, Belfast.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 47 Dartmouth-road, Willesden Green, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., M.P., F.C.S. 64 Pont-street, S.W.
1883. ‡Fitch, Rev. J. J. 5 Chambres-road, Southport.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1885. *FITZGERALD, Professor MAURICE, B.A. (Local Sec. 1902.) 32 Eglantine-avenue, Belfast.
1894. ‡Fitzmaurice, M., C.M.G., M.Inst.C.E. London County Council, Spring-gardens, S.W.
1888. *FITZPATRICK, Rev. THOMAS C. Christ's College, Cambridge.
1904. §Flather, J. H., M.A. Camden House, 90 Hills-road, Cambridge.
1897. ‡Flavelle, J. W. 565 Jarvis-street, Toronto, Canada.
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.
1904. §Fleming, James. 198 York-street, Belfast.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, Glasgow.
1876. ‡Fleming, Sir Sandford, K.C.M.G., F.G.S. Ottawa, Canada.
1870. ‡Fletcher, B. Edgington. Marlingford Hall, Norwich.
1890. ‡Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. ‡Fletcher, George, F.G.S. Dawson Court, Blackrock, co. Dublin.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 35 Woodville-gardens, Ealing, W.
1901. ‡Flett, J. S., M.A., D.Sc., F.R.S.E. 28 Jermyn-street, S.W.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1890. *FLUX, A. W., M.A., Professor of Political Economy in McGill University, Montreal, Canada.
1877. ‡Foale, William. The Croft, Madeira Park, Tunbridge Wells.
1891. ‡Foldvary, William. Museum Ring, 10, Buda Pesth.
1903. §Foord-Kelcey, W., Professor of Mathematics in the Royal Military Academy, Woolwich. The Shrubbery, Shooter's Hill, S.E.

Year of Election.

1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, E.C.
1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.
1883. ‡Forbes, Henry O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1897. ‡Forbes, J., K.C. Hazeldean, Putney-hill, S.W.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡Ford, J. Rawlinson (Local Sec. 1890). Quarry Dene, Weetwood-lane, Leeds.
1875. *Fordham, H. George. Odsey, Ashwell, Baldock, Herts.
1894. ‡*Forrest, Frederick. Beechwood, Castle Hill, Hastings.*
1887. ‡Forrest, The Right Hon. Sir John, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1902. §Forster, M. O., Ph.D. Royal College of Science, S.W.
1883. ‡Forsyth, A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897), Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1900. ‡Forsyth, D. Central Higher Grade School, Leeds.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1896. ‡Forwood, Sir William B., J.P. Ramleh, Blundellsands, Liverpool.
1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.
1883. ‡Foster, Lady. 86 Coleherne-court, Earl's Court, S.W.
1857. *Foster, George Carey, B.A., LL.D., D.Sc., F.R.S. (General Treasurer, 1898–1904; Pres, A, 1877; Council 1871–76, 1877–82.) Ladywalk, Rickmansworth.
1896. ‡Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.
1859. *Foster, Sir Michael, K.C.B., M.P., M.A., M.D., LL.D., D.C.L., F.R.S., F.L.S. (President, 1899; Gen. Sec. 1872–76; Pres. I, 1897; Council, 1871–72). Great Shelford, Cambridge.
1901. §Foster, T. Gregory, Ph.D., Principal of University College, W.C. Chester-road, Northwood, Middlesex.
1903. §Fourcade, H. G. Forest Department, Cape Town.
1896. ‡Fowkes, F. Hawkshead, Ambleside.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.
1901. ‡Fowlis, William. 45 John-street, Glasgow.
1883. *Fox, Charles. The Pynes, Warlingham-on-the-Hill, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. (Pres. G, 1896.) 28 Victoria-street, Westminster, S.W.
1904. *Fox, Charles J. J., B.Sc., Ph.D. 33 Ashley-road, Crouch Hill, N.
1904. §Fox, Francis Douglas, M.A., M.Inst.C.E. 28 Victoria-street, S.W.
1896. ‡Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox, Thomas. Pyles Thorne House, Wellington, Somerset.
1881. *Foxwell, Herbert S., M.A., F.S.S. (Council 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.

Year of Election.

1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901), Professor of Chemistry in the University of Birmingham.
1894. ‡Franklin, Mrs. E. L. 50 Porchester-terrace, W.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. *Fraser, Alexander, M.B., Professor of Anatomy in the Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. (Local Sec. 1885.) 232 Union-street, Aberdeen.
1892. ‡Fraser, Mrs. J. G. 4 Parkside, Cambridge.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. ‡FRASER, Sir THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council 1897–1903.) 4 Lower Sloane-street, S.W.
1886. ‡FRESHFIELD, DOUGLAS W., F.R.G.S. (Pres. E. 1904.) 1 Airlie-gardens, Campden Hill, W.
1901. ‡Frew, William, Ph.D. King James-place, Perth.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1892. *Frost, Edmund, M.B. Chesterfield-road, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1899. ‡Fry, Edward W. Cannon-street, Dover.
1898. ‡FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1898. ‡*Fry, Francis J. Leigh Woods, Clifton, Bristol.*
1875. *Fry, Joseph Storrs. 17 Upper Belgrave-road, Clifton, Bristol.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1895. ‡FULLARTON, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. ‡FULLER, FREDERICK, M.A. (Local Sec. 1859.) 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. (Local Sec. 1874). 71 Lexham-gardens, Kensington, W.
1884. ‡Fuller, William, M.B. Oswestry.
1891. ‡*Fulton, Andrew. 23 Park-place, Cardiff.*

1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1896. ‡Gair, H. W. 21 Water-street, Liverpool.
1850. ‡GAIRDNER, Sir W. T., K.C.B., M.D., LL.D., F.R.S. 32 George-square, Edinburgh.
1885 *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J., M.P. The Cottage, Seymour-grove, Old Trafford, Manchester.
1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.

Year of Election.

1860. *Galton, Francis, M.A., D.C.L., D.Sc., F.R.S., F.R.G.S. (Gen. Sec. 1863–68; Pres. E, 1862, 1872; Pres. H, 1885; Council 1860–63). 42 Rutland-gate, Knightsbridge, S.W.

1870. §Gamble, Lieut.-Colonel Sir D., Bart., K.C.B. St. Helens, Lancashire.

1889. ‡Gamble, David. Ratonagh, Colwyn Bay.

1870. †Gamble, J. C. St. Helens, Lancashire.

1888. *Gamble, J. Sykes, C.I.E., M.A., F.R.S., F.L.S. Highfield, East Liss, Hants.

1877. ‡Gamble, William. St. Helens, Lancashire.

1868. ‡Gamgee, Arthur, M.D., F.R.S. (Pres. D, 1882; Council 1888–90). 5 Avenue du Kursaal, Montreux, Switzerland.

1899. *Garcke, E. Ditton House, near Maidenhead.

1898. ‡Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.

1900. §Gardiner, J. Stanley, M.A. Dunstall, Newton-road, Cambridge.

1887. ‡Gardiner, Walter, M.A., F.R.S. 45 Hills-road, Cambridge.

1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.

1896. ‡Gardner, James. The Groves, Grassendale, Liverpool.

1894. ‡*Gardner, J. Addyman. 5 Bath-place, Oxford.*

1882. ‡Gardner, John Starkie. 29 Albert Embankment, S.E.

1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.

1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, S.W.

1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.

1883. ‡Garson, J. G., M.D. (Assist. Gen. Sec. 1902–04.) 14 Stratford-pl., W.

1903. ‡Garstang, A. H. 20 Roe-lane, Southport.

1903. *Garstang, T. James, M.A. Bedale's School, Petersfield, Hampshire.

1894. *Garstang, Walter, M.A., F.Z.S. Marine Biological Laboratory, Plymouth.

1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.

1882. ‡Garton, William. Woolston, Southampton.

1892. ‡*Garvie, James. Bolton's Park, Potter's Bar.*

1889. ‡Garwood, Professor E. J., M.A., F.G.S. University College, Gower-street, W.C.

1870. *Gaskell, Holbrook. Erindale, Frodsham, Cheshire.

1896. *Gaskell, Walter Holbrook, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council 1898–1901.) The Uplands, Great Shelford, near Cambridge.

1896. ‡Gatehouse, Charles. Westwood, Noctorum, Birkenhead.

1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.

1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.

1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.

1885. ‡Geddes, Professor Patrick. Ramsay-garden, Edinburgh.

1887. ‡*Gee, W. W. Haldane. Owens College, Manchester.*

1867. ‡Geikie, Sir Archibald, LL.D., D.Sc., Sec.R.S., F.R.S.E., F.G.S. (President, 1892; Pres. C. 1867, 1871, 1899; Council 1888–91.) 10 Chester-terrace, Regent's-park, N.W.

1871. ‡Geikie, James, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; Pres. E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.

1898. §Gemmill, James F., M.A., M.D. 21 Endsleigh-gardens, Partickhill, Glasgow.

1882. *Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.

Year of Election.

1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
1902. *Gepp, Antony, M.A., F.L.S. British Museum (Natural History), Cromwell-road, S.W.
1899. *Gepp, Mrs. A. 26 West Park-gardens, Kew.
1885. ‡*Gerard, Robert. Blair-Devenick, Cults, Aberdeen.*
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1865. ‡*Gibbins, William. Battery Works, Digbeth, Birmingham.*
1902. ‡Gibson, Andrew. 14 Cliftonville-avenue, Belfast.
1874. ‡Gibson, The Right Hon. Edward, K.C. 23 Fitzwilliam-square, Dublin.
1892. ‡Gibson, Francis Maitland. Care of Professor Gibson, 20 George-square, Edinburgh.
1901. §Gibson, Professor George A., M.A. 8 Sandyford-place, Glasgow
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E. 3 Drumsheugh-gardens, Edinburgh.
1892. ‡Gibson, James. 20 George-square, Edinburgh.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1904. *Gibson. Mrs. Margaret D. Castle Brae, Chesterton-road, Cambridge.
1896. ‡GIBSON, R. J. HARVEY, M.A., F.R.S.E., Professor of Botany in the University of Liverpool.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. *GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. (Pres. F, 1887, 1901.) Chanctonbury, Hayward's Heath.
1898. *Gifford, J. William. Oaklands, Chard.
1884. ‡Gilbert E. E. 245 St. Antoine-street, Montreal, Canada.
1883. §Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡Gilchrist, J. D. F., M.A., Ph.D., B.Sc. Marine Biologist's Office, Department of Agriculture, Cape Town.
1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Frognal Bank, Finchley-road, Hampstead, N.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, Sir DAVID, K.C.B., LL.D., D.Sc., F.R.S., F.R.A.S. (Vice-President, 1905.) Royal Observatory, Cape Town.
1902. §Gill, James F. 72 Strand-road, Bootle, Liverpool.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. 28 Stamford Hill-mansions, Stamford Hill, N.
1904. §GINN, S. R., D.L. (Local Sec. 1904.) Brookfield, Trumpington-road, Cambridge.
1900. §Ginsburg, Benedict W., M.A., LL.D. 23 Ladbroke-square, W.
1867. ‡GINSBURG, C. D., LL.D. Oakthorpe, Palmer's Green, N.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1883. *Gladstone, Miss. 19 Chepstow-villas, Bayswater, W.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council 1878–86.) Trinity College, Cambridge.
1901. ‡Glaister, Professor John, M.D., F.R.S.E. 18 Woodside-place, Glasgow.
1897. ‡Glashan, J. C., LL.D. Ottawa, Canada.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.

Year of Election.

1881. *GLAZEBROOK, R. T., M.A., D.Sc., F.R.S. (Pres. A, 1893; Council 1890–94.) Director of the National Physical Laboratory. Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1859. ‡Glennie, J. S. Stuart, M.A. Sandycroft, Haslemere, Surrey.
1874. ‡*Glover, George T. Corby, Hoylake.*
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. (Local Sec. 1873.) 16 Booth-street, Bradford, Yorkshire.
1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. Wakes Colne Place, Essex.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. (Pres. E, 1883). Nore, Godalming.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1898. ‡Goldney, F. Bennett, F.S.A. Goodnestone Park, Dover.
1886. ‡GOLDSMID, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. (Pres. E, 1886.) 29 Phœnix Lodge-mansions, Brook Green, W.
1899. ‡GOMME, G. L., F.S.A. 24 Dorset-square, N.W.
1890. *GONNER, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in the University of Liverpool.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1884. *Goodridge, Richard E. W. Lupton, Michigan, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's-mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M., D.Sc. 1 Rubislaw-terrace, Aberdeen.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Fairview, Dartmouth, Devon.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1865. ‡GORE, GEORGE, LL.D., F.R.S. 20 Easy-row, Birmingham.
1901. §GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901). Queen Anne's-mansions, S.W.
1875. *GOTCH, FRANCIS, M.A., B.Sc., F.R.S. (Council, 1901–), Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Edison House, Brighton.
1901. ‡GOURLAY, ROBERT. Glasgow.
1901. §Gow, Leonard. Hayston, Kelvinside, Glasgow.
1876. ‡Gow, Robert. Cairndowan, Dowanhill-gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill-gardens, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.

Year of Election.

1886. ‡Grabham, Michael C., M.D. Madeira.
1901. ‡Graham, Robert. 165 Nithsdale-road, Pollokshields, Glasgow.
1902. *Graham, William, M.D. District Lunatic Asylum, Belfast.
1875. ‡GRAHAME, JAMES (Local Sec. 1876). Reform Club, Pall Mall, S.W.
1904. §Gramont, Comte Armand de. 81 Rue de Lille, Paris.
1892. ‡Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. ‡*Grant, W. B. 10 Ann-street, Edinburgh.*
1864. ‡Grantham, Richard F., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1899. ‡Gray, Albert Alexander. 16 Berkeley-terrace, Glasgow.
1890. ‡GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1899. ‡Gray, Charles. 11 Portland-place, W.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1903. §Gray, Ernest, M.A., M.P. 99 Grosvenor-road, S.W.
1902. ‡*Gray, G., M.D. Newcastle, Co. Down.*
1904. § Gray, Rev. H. B., D.D. The College, Bradfield, Berkshire.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1892. *Gray, James Hunter, M.A., B.Sc. 141 Hopton-road, Streatham, S.W.
1904. §Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. §GRAY, JOHN, B.Sc. 9 Park-hill, Clapham Park, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. §Gray, R. W. 7 Orme-court, Bayswater, W.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, N.W.
1872. *Grece, Clair J., LL.D. 146 Station-road, Redhill, Surrey.
1904. *Green, A. G. 2 Dartmouth-road, Brondesbury, N.W.
1904. §Green, F. W. Thornfield, Tunbridge Wells.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1902), Professor of Botany to the Pharmaceutical Society of Great Britain. 61A St. Andrew's-street, Cambridge.
1903. §Green, W. J. 22 Sheepcote-road, Harrow.
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 1 Staple Inn, W.C.
1881. ‡Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, N.W.

Year of Election.

1898. *GREENLY, EDWARD. Achnashean, near Bangor, North Wales.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C. Beechfield, Poynton, Cheshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡Greenwood, F., M.B. Brampton, Chesterfield.
1887. ‡Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1894. *GREGORY, Professor J. WALTER, D.Sc., F.R.S., F.G.S. The University, Glasgow.
1896. *Gregory, Professor R. A., F.R.A.S. Dell Quay House, near Chichester.
1904. §Gregory, R. P. St. John's College, Cambridge.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Selworthy, College-road, Harrow.
1884. ‡GRIFFITHS, E. H., M.A., D.Sc., F.R.S., Principal of University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1903. ‡Griffiths, Thomas, J.P. 101 Manchester-road, Southport.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1888. *Grimshaw, James Walter, M.Inst.C.E. 5 Elchester-gardens, Bayswater, W.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1894. ‡GROOM, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
1894. §Groom, T. T., D.Sc. University College, Reading.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1904. §Grosvenor, G. H. New College, Oxford.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. Rockdale, Orwell-road, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. 45 Ladbroke-grove, W.
1897. ‡Grünbaum, O. F. F., B.A., D.Sc. 45 Ladbroke-grove, W.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡GUILLEMARD, F. H. H., M.A., M.D. The Mill House, Trumpington, Cambridge.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, Sir John. Llandaff House, Llandaff.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., F.L.S., F.Z.S. (Pres. D, 1880.) 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1904. §Gurney, Eustace. Sprowston Hall, Norwich.
1902. *Gurney, Robert. Ingham Old Hall, Stalham, Norfolk.
1883. ‡Guthrie, Malcolm. Prince's-road, Liverpool.
1896. ‡*Guthrie, Tom, B.Sc. Yorkshire College, Leeds.*

Year of Election.

1904. §Guttmann, Leo F., Ph.D. 18 Aberdare-gardens, N.W.
1876. ‡GWYTHER, R. F., M.A. Owens College and 33 Heaton-road, Withington, Manchester.

1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, M.A., D.Sc., F.R.S., F.Z.S. (Pres. H, 1902; Council, 1902– .) Inisfail, Hills-road, Cambridge.
1888. *Hadfield, R. A., M.Inst.C.E. Parkhead House, Sheffield.
1892. ‡*Haigh, E., M.A. Longton, Staffordshire.*
1870. ‡Haigh, George. 27 Highfield South, Rockferry, Cheshire.
1879. ‡*HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.*
1899. ‡Hall, A. D., M.A., Director of the Rothamsted Experiment Station, Harpenden, Herts.
1903. §HALL, E. MARSHALL, K.C., M.P. 75 Cambridge-terrace, W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. Jessop Hospital, Sheffield.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Cissbury Court, West Worthing, Sussex.
1898. §Hall, James P. The 'Tribune,' New York, U.S.A.
1899. ‡Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1885. §Hall, Samuel, F.I.C., F.C.S. 19 Aberdeen-park, Highbury, N.
1900. ‡Hall, T. Farmer, F.R.G.S. 39 Gloucester-square, Hyde Park, W.
1896. ‡Hall, Thomas B. Larch Wood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1896. ‡Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, W.
1891. *Hallett, George. Oak Cottage, West Malvern.
1891. ‡Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S. (Pres. I, 1902; Council 1897–1903), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, N.W.
1904. *Hallidie, A. H. S. Avondale, Chesterfield-road, Eastbourne.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Fairley, Weston, Bath.
1904. *Hamel de Manin, Anna Countess de. 35 Circus-road, N.W.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 41 Queen's-road, Aberdeen.
1902. ‡HAMILTON, Rev. T., D.D. Queen's College, Belfast.
1881. *Hammond, Robert. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. Lenqua da Cà, Alassio, Italy.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. 17 Percy-street, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, S.W.
1897. ‡*HANCOCK, HARRIS. University of Chicago, U.S.A.*
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1884. ‡Hannaford, E. P., M.Inst.C.E. 2573 St. Catherine-street, Montreal.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1902. ‡Harbison, Adam, B.A. 5 Ravenhill-terrace, Ravenhill-road, Belfast.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., V.P.C.S. (GEN. SEC. 1883–97; Pres. B, 1875; Council 1881–83). St. Clare, Ryde, Isle of Wight.

Year of Election.

1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. (Pres. G, 1895; Council 1895–1901). 6 Queen Anne's-gate, S.W.
1897. §Harcourt, Hon. R., LL.D., K.C., Minister of Education for the Province of Ontario. Toronto, Canada.
1886. *Hardcastle, Colonel Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1902. *HARDCASTLE, Miss FRANCES. 14 Huntingdon-road, Cambridge.
1903. *Hardcastle, J. Alfred. The Dial House, Crowthorne, Berkshire.
1892. *HARDEN, ARTHUR, Ph.D., M.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, Grosvenor-road, S.W.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1894. ‡Hardman, S. C. 120 Lord-street, Southport.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1898. ‡Harford, W. H. Oldown House, Almondsbury.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *HARKER, ALFRED, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1896. ‡Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1871. ‡*Harkness, William, F.C.S. 1 St. Mary's-road, Canonbury, N.*
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. **Harley, Harold. 14 Chapel-street, Bedford-row, W.C.*
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.
1899. ‡Harman, Dr. N. Bishop. St. John's College, Cambridge.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., D.Sc., F.R.S. King's College, Cambridge.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1903. ‡Harris, Robert, M.B. 18 Duke-street, Southport.
1898. ‡Harrison, A. J., M.D. Failand Lodge, Guthrie-road, Clifton, Bristol.
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1904. §Harrison, E. K. Trinity College, Cambridge.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1904. §Harrison, Frank L. 83 Clarkehouse-road, Sheffield.
1904. §Harrison, H. Spencer. 137 Richmond-road, Cardiff.
1889. ‡Harrison, J. C. Oxford House, Castle-road, Scarborough.
1858. *HARRISON, J. PARK, M.A. 22 Connaught-street, Hyde Park, W.
1892. ‡HARRISON, JOHN (Local Sec. 1892). Rockville, Napier-road, Edinburgh.
1870. ‡HARRISON, REGINALD, F.R.C.S. (Local Sec. 1870). 6 Lower Berkeley-street, Portman-square, W.

Year of Election.

1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1895. ‡Harrison, Thomas. 48 High-street, Ipswich.
1901. *Harrison, W. E. 15 Lansdowne-road, Handsworth, Staffordshire.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1885. ‡HART, Colonel C. J. (Local Sec. 1886.) Highfield Gate, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1903. *Hart, Thomas Clifford. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *HARTLAND, E. SIDNEY, F.S.A. Highgarth, Gloucester.
1897. ‡Hartley, E. G. S. Wheaton Astley Hall, Stafford.
1871 *HARTLEY, WALTER NOEL, D.Sc., F.R.S., F.R.S.E., F.C.S. (Pres. B, 1903), Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. ‡Hartley, W. P., J.P. Aintree, Liverpool.
1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡HARTOG, P. J., B.Sc. University of London, South Kensington, S.W.
1897. ‡Harvey, Arthur. Rosedale, Toronto, Canada.
1898. ‡Harvey, Eddie. 10 The Paragon, Clifton, Bristol.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1903. *Hastie, Miss J. A. Care of Messrs. Street & Co., 30 Cornhill, E.C.
1903. §Hastie, William. 20 Elswick-row, Newcastle-on-Tyne.
1904. §Hastings, G. 15 Oak-lane, Bradford, Yorkshire.
1875. *HASTINGS, G. W. (Pres. F, 1880.) Chapel House, Chipping Norton.
1903. §Hastings, W. G. W. Chapel House, Chipping Norton.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1903. ‡Hathaway, Herbert G. 45 High-street, Bridgnorth, Salop.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
1904. *Haughton, W. T. H. The Highlands, Great Barford, St. Neots.
1904. §Havilland, Hugh de. Eton College, Windsor.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council 1881–87.) 22 Down-street, W., and 33 Great George-street, S.W.
1897. §HAWKSLEY, CHARLES, M.Inst.C.E. (Pres. G, 1903; Council, 1902– .) 30 Great George-street, S.W.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., G.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *HAYCRAFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology in University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1900. §Hayden, H. H., B.A., F.G.S. Geological Survey, Calcutta, India.
1903. *Haydock, Arthur. 197 Preston New-road, Blackburn.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896. ‡Hayes, Rev. F. C. The Rectory, Raheny, Dublin.
1896. ‡Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1898. ‡Hayman, C. A. Kingston Villa, Richmond Hill, Clifton, Bristol.

Year of
Election.

1903. §Hayward, Joseph William, M.Sc. 29 Bishop's-mansions, Fulham, S.W.
1896. *Haywood, Lieut.-Colonel A. G. Rearsby, Merrilocks-road, Blundell-sands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. ‡Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A. Heyroun, Chaucer-road, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep. 195 Union-street, Plymouth.
1898. *Heath, Rev. Arthur J., B.A., F.G.S. 71 St. Michael's-hill, Redland, Bristol.
1902. ‡Heath, J. W. Royal Institution, Albemarle-street, W.
1898. ‡HEATH, R. S., M.A., D.Sc. The University, Birmingham.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1902. §Heathorn, Captain T. B., R.A. 10 Wilton-place, Knightsbridge, S.W.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1892. *HEATON, WILLIAM H., M.A. (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, S.E.
1888. *Heawood, Percy J., Lecturer in Mathematics in Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 10 Cranley-place, South Kensington, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E. 27 Ullet-road, Liverpool.
1901. *Heller, W. M., B.Sc. 18 Belgrave-square, Monkstown, Co. Dublin.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1897. §Hemming, G. W., K.C. 2 Earl's Court-square, S.W.
1899. §Hemsalech, G. A., D.Sc. The Owens College, Manchester.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Henderson, Mrs. A. L. Westmoor Hall, Brimsdown, Middlesex.
1901. ‡Henderson, Rev. Andrew, LL.D. Castle Head, Paisley.
1891. *HENDERSON, G. G., D.Sc., M.A., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. ‡*Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.*
1880. *Henderson, Rear-Admiral W. H., R.N. Royal Dockyard, Devonport.
1896. ‡*Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.*
1904. *Hendrick, James. Marischal College, Aberdeen.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883-89), Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 34 Clarendon-road, Notting Hill, W.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E., Professor of Anatomy in University College, Cardiff.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Oakfield Cottage, Dartford Heath, Kent.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.

Year of Election.

1904. §Hepworth, Commander M. W. C., R.N.R., C.B. Meteorological Office, Victoria-street, S.W.
1892. *HERBERTSON, ANDREW J., Ph.D., F.R.S.E., F.R.G.S. 4 Broad-street, Oxford.
1902. ‡Herdman, G. W., B.Sc., Assoc.M.Inst.C.E. 2 Fyfield-road, Enfield.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S. (GENERAL SECRETARY, 1903– ; Pres. D, 1895; Council, 1894–1900; Local Sec. 1896), Professor of Natural History in the University of Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1875. ‡HEREFORD, The Right Rev. JOHN PERCIVAL, D.D., LL.D., Lord Bishop of. (Pres. L, 1904.) The Palace, Hereford.
1891. ‡*Hern, S. South Cliff, Marine Parade, Penarth.*
1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham. Observatory House, Slough, Bucks.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, J. C. W. Littlemore, Oxford.
1900. ‡Herschel, Sir W. J., Bart. Littlemore, Oxford.
1903. *HESKETH, CHARLES H. B., M.A. The Rookery, North Meols, Southport.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.
1894. ‡HEWETSON, G. H. (Local Sec. 1896.) 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A. S., M.A., F.S.S., Professor of Political Economy in King's College, Strand, W.C.
1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.
1903. ‡Hewitt, E. G. W. 87 Princess-road, Moss Side, Manchester.
1903. ‡Hewitt, John Theodore, M.A., D.Sc., Ph.D. 8 Montpellier-road, Twickenham.
1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Junior Constitutional Club, Piccadilly, W.
1882. *HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.R.G.S. 27 Arkwright-street, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1897. ‡Heys, Thomas. 130 King-street West, Toronto, Canada.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1879. ‡Heywood, Sir A. Percival, Bart. Duffield Bank, Derby.
1886. ‡HEYWOOD, HENRY, J.P. Witla Court, near Cardiff.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
1888. ‡Hichens, James Harvey, M.A. The School House, Wolverhampton.
1898. ‡Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S. (Pres. A, 1895), Principal of University College, Sheffield. Dunheved, Endcliffe-crescent, Sheffield.
1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S. (Pres. D, 1903), Professor of Zoology in Victoria University, Manchester.
1864. *HIERN, W. P., M.A., F.R.S. The Castle, Barnstaple.
1891. ‡HIGGS, HENRY, LL.B., F.S.S. (Pres. F, 1899; Council 1904.) H.M. Treasury, Whitehall, S.W.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1903. *Hill, Arthur W. King's College, Cambridge.
1881. *HILL, Rev. EDWIN, M.A. The Rectory, Cockfield, Bury St. Edmunds.

Year of Election.

1887. ‡Hill, G. H., M.Inst.C.E., F.G.S. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1898. *Hill, Thomas Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in the University of Birmingham. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1903. *Hilton, Harold. Bryn Teg-terrace, Bangor, North Wales.
1903. §HIND, Dr. WHEELTON, F.G.S. Roxeth House, Stoke-on-Trent.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1886. ‡Hingley, Sir Benjamin, Bart. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, Sir WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1900. §Hinks, Arthur R., M.A. 10 Huntingdon-road, Cambridge.
1903. *Hinmers, Edward. Glentwood, South Down-drive, Hale, Cheshire.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1899. §Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1887. *Hobson, Bernard, M.Sc., F.G.S. Thornton, Didsbury, near Manchester.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1904. §Hobson, Ernest William, Sc.D., F.R.S. The Gables, Mount Pleasant, Cambridge.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. ‡Hodgkinson, Arnold. 22 Park-road, Southport.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glenluce-road, Blackheath, S.E.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson R. W. 7 Sandhill, Newcastle-upon-Tyne.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1896. ‡Hodgson, Dr. William, J.P. Helensville, Crewe.
1904. §Hodson, F. Bedale's School, Petersfield, Hampshire.
1904. §Hogarth, D. G., M.A. Chapel Meadow, Forest Row, Sussex.
1894. ‡Hogg, A. F., M.A. 13 Victoria-road, Darlington.
1894. ‡Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 73 Albert-road, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.

Year of Election.

1887. *Holder, Henry William, M.A. Sheet, near Petersfield.
1896. ‡Holder, Thomas. 2 Tithebarn-street, Liverpool.
1900. §Holdich, Colonel Sir Thomas H., R.E., K.C.B., K.C.I.E., F.R.G.S. (Pres. E, 1902.) 41 Courtfield-road, S.W.
1887. *Holdsworth, C. J. Sunnyside, Wilmslow, Cheshire.
1891. ‡Holgate, Benjamin, F.G.S. The Briers, North Park-avenue, Roundhay, Leeds.
1904. §Holland, Charles E. 9 Downing-place, Cambridge.
1903. §Holland, J. L., B.A. 72 Kingsley Park-terrace, Northampton.
1896. ‡Holland, Mrs. Lowfields House, Hooton, Cheshire.
1898. ‡Holland, Thomas H., F.R.S., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard, M.D. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1903. *Holt, Alfred, jun., J.P. Crofton, Aigburth, Liverpool.
1896. ‡Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. ‡Holterman, R. F. Brantford, Ontario, Canada.
1875. *Hood, John. Chesterton, Cirencester.
1904. §Hooke, Rev. D. Burford. Bonchurch Lodge, Barnet.
1847. ‡Hooker, Sir Joseph Dalton, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (President, 1868; Pres. E, 1881; Council 1866–67.) The Camp, Sunningdale, Berkshire.
1892. ‡Hooker, Reginald H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Streatham Common, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1904. §Hopewell-Smith, A., M.R.C.S. 37 Park-street, Grosvenor-square, S.W.
1901. *Hopkinson, Bertram, M.A. Holmwood, Wimbledon.
1884. *Hopkinson, Charles (Local Sec. 1887). The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Ferns, Alderley Edge, Cheshire.
1871. *Hopkinson, John, Assoc.M.Inst.C.E., F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond-street, W.; and Weetwood, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
1898. *Hornby, R., M.A. Haileybury College, Hertford.
1885. ‡Horne, John, LL.D., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1901.) Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1903. §Horne, William, F.G.S. Leyburn, Yorkshire.
1902. ‡Horner, John. Chelsea, Antrim-road, Belfast.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Falmouth House, 20 Hyde Park-terrace, W.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *Horsley, Sir Victor A. H., B.Sc., F.R.S., F.R.C.S. (Council, 1893–98.) 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. ‡Hotblack, J. T. 45 Newmarket-road, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S., F.R.S. Royal Observatory, Cape Town.

Year of Election.

1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. 35 Grosvenor-place, S.W.
1896. ‡Hoult, J. South Castle-street, Liverpool.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, S.E.
1893. ‡Howard, F. T., M.A., F.G.S. The Cottage, Poynton, Stockport.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1899. §Howard-Hayward, H. 16 Blakesley-avenue, Ealing, W.
1901. §Howarth, E. Public Museum, Weston Park, Sheffield.
1903. *Howarth, James H., F.G.S. Somersley, Rawson-avenue, Halifax.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1899. ‡Howden, Ian D. C. 6 Cambridge-terrace, Dover.
1889. ‡Howden, Robert, M.B., Professor of Anatomy in the University of Durham College of Medicine. Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S. 13 Cobden-crescent, Edinburgh.
1898. ‡Howell, J. H. 104 Pembroke-road, Clifton, Bristol.
1891. ‡Howell, Rev. William Charles, M.A. Holy Trinity Parsonage, High Cross, Tottenham, N.
1886. ‡Howes, G. B., LL.D., D.Sc., F.R.S., F.L.S. (Pres. D, 1902; Council, 1902–04), Professor of Zoology in the Royal College of Science, South Kensington, S.W.
1901. ‡Howie, Robert Y. 3 Greenlaw-avenue, Paisley.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1865. *Howlett, Rev. Frederick, F.R.A.S. 7 Prince's-buildings, Clifton, Bristol.
1863. ‡Howorth, Sir H. H., K.C.I.E., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1883. ‡*Howorth, John, J.P. Springbank, Burnley, Lancashire.*
1883. ‡Hoyle, James. Blackburn.
1887. §Hoyle, William E., M.A., D.Sc. Victoria University, Manchester.
1903. §Hübner, Julius. Ash Villa, Cheadle Hulme, Cheshire.
1888. ‡Hudd, Alfred E., F.S.A. Clinton House, Pembroke-road, Clifton, Bristol.
1898. §Hudleston, W. H., M.A., F.R.S., F.G.S. (Pres. C, 1898.) 8 Stanhope-gardens, S.W.
1867. *Hudson, William H. H., M.A. 15 Altenberg-gardens, Clapham Common, S.W.
1858. *Huggins, Sir William, K.C.B., D.C.L. Oxon., LL.D. Camb., Pres.R.S., F.R.A.S. (President, 1891; Council, 1868–74, 1876–84.) 90 Upper Tulse-hill, S.W.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester
1883. ‡Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. ‡Hughes, John W. New Heys, Allerton, Liverpool.
1891. ‡Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §Hughes, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge. (Council, 1879–86.) Ravensworth, Brooklands-avenue, Cambridge.
1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1867. ‡Hull, Edward, M.A., LL.D., F.R.S., F.G.S. (Pres. C., 1874.) 14 Stanley-gardens, Notting Hill, W.

Year of Election.

1903. ‡Hulton, Campbell G. Palace Hotel, Southport.
1897. ‡Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.
1901. ‡Hume, John H. Toronto, Canada; and 63 Bridgegate, Irvine.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, S.W.
1904. *Humphreys, Alexander C., Sc.D., LL.D., President of the Stevens Institute of Technology, Hoboken, New Jersey, U.S.A.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡*Hunt, Charles. The Gas Works, Windsor-street, Birmingham.*
1891. ‡Hunt, D. de Vere, M.D. Aubrey House, Cathedral-road, Cardiff.
1875. *Hunt, William. North Cote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1901. ‡Hunter, G. M., Assoc.M.Inst.C.E. Newyards, Maybole, N.B.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1901. *Hunter, William. Evirallan, Stirling.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1898. ‡Hurle, J. Cooke. Southfield House, Brislington, Bristol.
1903. §Hurst, Charles C., F.L.S. Burbage, Hinckley.
1882. *Hurst, Walter, B.Sc. Kirkgate, Tadcaster, Yorkshire.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1894. *HUTCHINSON, A., M.A., Ph.D. (Local Sec. 1904.) Pembroke College, Cambridge.
1903. §Hutchinson, Rev. H. N. 94 Fellows-road, N.W.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864 *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., M.Sc. The Victoria University, Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. Physical Laboratory, Leiden, Netherlands.
1902. ‡Hyndman, Hugh. Crosshill, Windsor-avenue, Belfast.

1883. §Idris, T. H. W. 110 Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im Thurn, Everard F., C.B., C.M.G. Colombo, Ceylon.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡*Ingle, Herbert. Pool, Leeds.*
1901. ‡INGLIS, JOHN, LL.D. 4 Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A. (Pres. F. 1878), Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.

Year of Election.

1898. ‡Inskip, James. Clifton Park, Clifton, Bristol.
1901. *Ionides, Stephen A. 23 Second-avenue, Hove, Brighton.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1903. ‡Irving, W. B. 27 Park-road, Southport.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1901. §Jacks, William, LL.D. Crosslet, Dumbartonshire.
1883. *JACKSON, Professor A. H., B.Sc. 349 Collins-street, Melbourne, Australia.
1903. §Jackson, C. S. 96 Herbert-road, Woolwich, S.E.
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. 35 Leyland-road, Southport.
1883. ‡Jackson, Mrs. F. J. 35 Leyland-road, Southport.
1899. ‡Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James, F.R.Met.Soc. Seabank, Girvan, N.B.
1898. *Jackson, Sir John. 51 Victoria-street, S.W.
1869. §Jackson, Moses, J.P. The Orchards, Whitchurch, Hants.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Villa Jaffe, 38 Prom. des Anglais, Nice, France.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry, J.P. 64 Park-place, Cardiff.
1891. *James, Charles Russell. 5 Raymond-buildings, Gray's Inn, W.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡*James, Frank. Portland House, Aldridge, near Walsall.*
1891. ‡James, Ivor. University College, Cardiff.
1896. ‡James, O. S. 192 Jarvis-street, Toronto, Canada.
1904. §James, Thomas Campbell. 4 Belmont-terrace, Llanelly.
1858. ‡James, William C. Woodside, Plymouth.
1896. **Jameson, H. Lyster, M.A., Ph.D. Technical College, Derby.*
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1903. ‡JARRATT, J. ERNEST. (Local Sec. 1903.) 10 Cambridge-road, Southport.
1870. ‡Jarrold, John James. London-street, Norwich.
1904. *Jeans, J. H. Trinity College, Cambridge.
1904. §Jebb, Sir R. C., Litt. D., M.P., Professor of Greek in the University of Cambridge. Springfield, Cambridge.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1894. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1873. ‡Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *JENKINS, Sir JOHN JONES. The Grange, Swansea.

Year of Election.

1903. §Jenkinson, J. W. The Museum, Oxford.
1904. §Jenkinson, W. W. 6 Moorgate-street, E.C.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Glen Helen, Narborough-road, Leicester.
1897. ‡Jennings, W. T., M.Inst.CE. Molson's Bank Buildings, Toronto, Canada.
1899. ‡Jepson, Thomas. Evington, Northumberland-street, Higher Broughton, Manchester.
1887. ‡JERVIS-SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1900. *Jevons, H. Stanley. 19 Chesterfield-gardens, Hampstead, N.W.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. ‡JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, N.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1902. *Johnson, Rev. W., B.A., B.Sc. Archbishop Holgate's Grammar School, York.
1898. *Johnson, W. Claude, M.Inst.C.E. The Dignaries, Blackheath, S.E.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1899. ‡Johnston, Colonel Duncan A., C.B., R.E. Ordnance Survey, Southampton.
1883. ‡JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. Queen Anne's-mansions, S.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883 ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S. Blantyre Lodge, Blantyre, N.B.
1888. ‡*Jolly, W. C. Home Lea, Lansdowne, Bath.*
1896. *JOLY, CHARLES JASPER, M.A., D.Sc., F.R.S., F.R.A.S., Royal Astronomer of Ireland and Andrews' Professor of Astronomy in the University of Dublin. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., F.G.S., Professor of Geology and Mineralogy in the University of Dublin. Geological Department, Trinity College, Dublin.
1898. ‡Jones, Sir Alfred L., K.C.M.G. Care of Messrs. Elder, Dempster, & Co., Liverpool.
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. Science and Art Department, South Kensington, S.W.
1904. §Jones, Miss E. Constance. Girton College, Cambridge.

Year of Election.

1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1903. §Jones, Evan. Ty-Mawr, Aberdare.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge-road, Waterloo, Liverpool.
1903. *JONES, H. O., M.A. Clare College, Cambridge.
1895. ‡Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, S.W.
1901. §Jones, R. E., J.P. Oakley Grange, Shrewsbury.
1902. ‡Jones, R. M., M.A. Royal Academical Institution, Belfast.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. (Pres. C, 1891.) 17 Parson's Green, Fulham, S.W.
1896. ‡Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1870. ‡JUDD, JOHN WESLEY, C.B., LL.D., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886–92), Professor of Geology in the Royal College of Science, London. 22 Cumberland-road, Kew.
1903. §Julian, Henry Forbes. Redholme, Braddon's Hill-road, Torquay.
1894. §Julian, Mrs. Forbes. Redholme, Braddon's Hill-road, Torquay.
1883. ‡Justice, Philip Middleton. 14 Southampton-buildings, Chancery-lane, W.C.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1904. §Kayser, Professor H. The University, Bonn, Germany.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. ‡*Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.*
1878. *Kelland, W. H. 80 Lothian-road, S.W.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. Ferring, near Worthing.
1902. *Kelly, William J., J.P. 25 Oxford-street, Belfast.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–1904.) 1 Savile-row, W.
1847. *KELVIN, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. (PRESIDENT, 1871; Pres. A, 1852, 1867, 1876, 1881, 1884.) Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.

Year of Election.

1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire; and 15 Eaton-place, S.W.

1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.

1898. *Kemp, John T., M.A. 4 Cotham-grove, Bristol.

1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.

1890. ‡Kempson, Augustus. Kildare, 17 Arundel-road, Eastbourne.

1891. §Kendall, Percy F., F.G.S., Professor of Geology in the University of Leeds.

1875. ‡Kennedy, Alexander B. W., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1894.) 1 Queen Anne-street, Cavendish-square, W.

1897. §Kennedy, George, M.A., LL.D. Crown Lands Department, Toronto, Canada.

1884. ‡Kennedy, George T., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.

1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.

1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.

1884. ‡Kennedy, William. Hamilton, Ontario, Canada.

1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.

1893. §Kent, A. F. Stanley, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.

1901. ‡Kent, G. 16 Premier-road, Nottingham.

1886. §Kenward, James, F.S.A. 43 Streatham High-road, S.W.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.

1881. ‡Kermode, Philip M. C. Claughbane, Ramsey, Isle of Man.

1884. ‡Kerr, James, M.D. Winnipeg, Canada.

1883. ‡Kerr, Rev. John, LL.D., F.R.S. Free Church Training College, 113 Hill-street, Glasgow.

1901. ‡Kerr, John G., LL.D. 15 India-street, Glasgow.

1892. ‡Kerr, J. Graham, M.A., Professor of Natural History in the University, Glasgow.

1889. ‡Kerry, W. H. R. The Sycamores, Windermere.

1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.

1869. *Kesselmeyer, Charles Augustus. Rose Villa, Vale-road, Bowdon, Cheshire.

1869. *Kesselmeyer, William Johannes. Elysée Villa, Manchester-road, Altrincham, Cheshire.

1903. §Kewley, James. King William's College, Isle of Man.

1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.

1902. §Kidd, George. Dunmurry, Co. Antrim.

1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.

1886. §Kidston, Robert, F.R.S., F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.

1897. ‡Kiekelly, Dr. John, LL.D. 46 Upper Mount-street, Dublin.

1901. *Kiep, J. N. 4 Hughenden-drive, Kelvinside, Glasgow.

1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.

1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.

1890. §Kimmins, C. W., M.A., D.Sc. Dame Armstrong House, Harrow.

1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.

1860. ‡Kinahan, G. Henry, M.R.I.A. Dublin.

1875. *Kinch, Edward, F.C.S. Royal Agricultural College, Cirencester.

1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.

1888. *King, E. Powell. Wainsford, Lymington, Hants.

1875. *King, F. Ambrose. Avonside, Clifton, Bristol.

Year of Election.

1899. ‡KING, Sir GEORGE, K.C.I.E., F.R.S. (Pres. K, 1899). Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Stonelands, West Hoathly.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
1883. *King, Joseph. Sandhouse, Witley, Godalming.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1901. ‡King, Robert. Levernholme, Nitshill, Glasgow.
1870. ‡King, William, M.Inst.C.E. 5 Beach Lawn, Waterloo, Liverpool.
1903. §Kingsford, H. S., B.A. Anthropological Institute, 3 Hanover-square, W.
1897. ‡Kingsmill, Nichol. Toronto, Canada.
1875. ‡KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. 2 Moray-place, Edinburgh.
1900. ‡KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. University College, Nottingham.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1870. ‡*Kitchener, Frank E. Newcastle, Staffordshire.*
1904. §Kitson, Arthur. 209 Gloucester-terrace, Hyde Park, W.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1901. §Kitto, Edward. The Observatory, Falmouth.
1886. ‡Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Gloucester-terrace, Regent's Park, N.W.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1898. ‡KNOCKER, Sir E. WOLLASTON, K.C.B. (Local Sec. 1899.) Castle Hill House, Dover.
1888. ‡KNOTT, Professor CARGILL G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Oak Hill, Windermere.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1903. ‡Knowlson, J. F. 26 Part-street, Southport.
1897. ‡Knowlton, W. H. 36 King-street East, Toronto, Canada.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
1902. ‡KNOX, R. KYLE, LL.D. 1 College-gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡KOHN, CHARLES A., Ph.D. Sir John Cass Technical Institute, Jewry-street, Aldgate, E.C.
1898. ‡Krauss, A. Hawthornden, Priory-road, Clifton, Bristol.
1890. *Krauss, John Samuel, B.A. Stonycroft, Knutsford-road, Wilmslow, Cheshire.
1901. ‡Kuenen, Professor J. P., Ph.D. University College, Dundee.
1888. *Kunz, G. F., M.A., Ph.D. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1870. ‡Kynaston, Josiah W., F.C.S. 3 Oak-terrace, Beech-street, Liverpool.

1885. *Laing, J. Gerard. 5 Pump-court, Temple, E.C.
1897. ‡Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1904. §Lake, Philip. St. John's, College, Cambridge.
1877. ‡Lake, W. C., M.D. Teignmouth.
1904. §Lamb, C. G. Ely Villa, Glisson-road, Cambridge.

Year of Election.

1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., LL.D., D.Sc., F.R.S. (Pres. A, 1904), Professor of Pure Mathematics in the Victoria University, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1896. ‡Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1903. ‡Lambert, Joseph. 9 Westmoreland-road, Southport.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. *LAMPLUGH, G. W., F.G.S. 13 Beaconsfield-road, St. Albans.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1904. §Landor, A. H. Savage, F.R.G.S. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. The University, Aberdeen.
1898. *Lang, William H. 10 Jedburgh-gardens, Kelvinside, Glasgow.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899; Council, 1904–), Professor of Physiology in the University of Cambridge. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S. (Pres. D, 1883; Council 1889–90, 1894–95, 1900–02), Director of the Natural History Museum, Cromwell-road, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University of Birmingham. 48 Frederick-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Craglands, Helen's Bay, Co. Down.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., Sec.R.S. (Pres. A, 1900), Lucasian Professor of Mathematics in the University of Cambridge. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Longridge, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1900. ‡Lauder, Alexander, Lecturer in Agricultural Chemistry in the Edinburgh and East of Scotland College of Agriculture, Edinburgh.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. 5 Pepys-road, Wimbledon, Surrey.
1891. ‡Laurie, A. P. Heriot Watt College, Edinburgh.
1892. ‡LAURIE, MALCOLM, B.A., D.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia, Canada.
1870. *Law, Channell. Ilsham Dene, Torquay.
1884. ‡Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡*Lawrence, Edward. Aigburth, Liverpool.*
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1900. ‡Lawrence, W. Trevor, Ph.D. 57 Prince's-gate, S.W.
1889. §Laws, W. G., M.Inst.C.E. 95 Osborne-road, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.

Year of Election.

1888. §Layard, Miss Nina F. Rookwood, Tonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, S.W.
1894. *LEAHY, A. H., M.A., Professor of Mathematics in University College, Sheffield. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1901. *Lean, George, B.Sc. 15 Park-terrace, Glasgow.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1904. *Leathem, J. G. St. John's College, Cambridge.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the Durham College of Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia, Canada.
1895. *Ledger, Rev. Edmund. Protea, Doods-road, Reigate.
1898. ‡LEE, ARTHUR, J.P. (Local Sec. 1898). 10 Berkeley-square, Clifton, Bristol.
1896. §Lee, Rev. H. J. Barton. 35 Cross Park-terrace, Heavitree, Exeter.
1891. ‡*Lee, Mark. The Cedars, Llandaff-road, Cardiff.*
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1892. *LEES, CHARLES H., D.Sc. 42 Lorne-grove, Fallowfield, Manchester.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896. ‡Lees, William. 10 Norfolk-street, Manchester.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. (Local Sec. 1882). Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, F.R.S. (Pres. F, 1879; Council 1878–80.) 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡LEHFELDT, ROBERT A. 56 Norfolk-square, W.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1903. §Leighton, G. R., M.D., F.R.S.E., Professor of Pathology in the Royal Veterinary College, Edinburgh.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1903. *Lempfort, R. G. K., M.A. Meteorological Office, 63 Victoria-street, S.W.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1902. ‡Lennox, R. N. Rosebank, Hammersmith, W.
1887. *Leon, John T. Elmwood, Grove-road, Southsea.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1901. §Leonard, J. H., B.Sc. 2 Carlingford-road, Hampstead, N.W.
1904. §Lepper, Alfred William. 6 Trinity College, Dublin.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. Royal Exchange, Manchester.
1883. ‡Lester, Thomas. Fir Bank, Penrith.

Year of Election.

1904. *Le Sueur, H. R., D.Sc. Chemical Laboratory, St. Thomas's Hospital, S.E.
1900. ‡Letts, Professor E. A., D.Sc., F.R.S.E. Queen's College, Belfast.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. ‡Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. ‡Levy, J. H. 11 Abbeville-road, Clapham Park, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, S.W.
1870. ‡Lewis, Alfred Lionel. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1904. §Lewis, Hugh. Glanafrau, Newton, Montgomeryshire.
1897. ‡Lewis, Rev. J. Pitt, M.A. Rossin House, Toronto, Canada.
1899. ‡Lewis, Thomas. 9 Hubert-terrace, Dover.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1903. §Lewkowitsch, Dr. J. 71 Priory-road, N.W.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1904. §Link, Charles W. Eversley, Chichester-road, Croydon.
1898. ‡Lippincott, R. C. Cann. Over Court, Almondsbury, near Bristol.
1883. ‡*Lisle, H. Claud. Nantwich.*
1895. *Lister, The Right Hon. Lord, F.R.C.S., D.C.L., D.Sc., F.R.S. (President, 1896.) 12 Park-crescent, Portland-place, W.
1888. ‡Lister, J. J., M.A., F.R.S. Leytonstone, Essex, N.E.
1861. *Liveing, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888-95; Local Sec. 1862), Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W.
1902. §Llewellyn, Evan. Working Men's Institute and Hall, Blaenavon.
1880. ‡Llewelyn, Sir John T. D., Bart., M.P. Penllegare, Swansea.
1903. §Lloyd, Godfrey I. H. Grindleford, near Sheffield.
1886. ‡Lloyd, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt., F.R.S.E 49a Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Wednesbury.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1854. *Lobley, J. Logan, F.G.S., F.R.G.S. 36 Palace-street, Buckingham Gate, S.W.
1892. §Loch, C. S., B.A. 15a Buckingham-street, W.C.
1904. §Lock, Rev. J. B. Herschel House, Cambridge.
1867. *Locke, John. 144 St. Olaf's-road, Fulham, S.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡Lockyer, Sir J. Norman, K.C.B., LL.D., F.R.S. (President, 1903; Council 1871-76, 1901-02.) 16 Penywern-road, S.W.
1902. *Lockyer, Lady. 16 Penywern-road, S.W.
1900. §Lockyer, W. J. S., Ph.D. 16 Penywern-road, S.W.
1886. *Lodge, Alfred, M.A. The Croft, Peperharow-road, Godalming.

Year of Election.

1875. *LODGE, Sir OLIVER J., D.Sc., LL.D., F.R.S. (Pres. A, 1891; Council, 1891–97, 1899–1903), Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. 225 Hagley-road, Birmingham.
1889. ‡Logan, William. Langley Park, Durham.
1896. §LOMAS, J., F.G.S. 13 Moss-grove, Birkenhead.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. ‡LONDONDERRY, The Marquess of, K.G., H.M. Lieutenant of the City of Belfast. Londonderry House, Park-lane, W.
1903. §Long, Frederick. The Close, Norwich.
1876. ‡Long, H. A. Brisbane, Queensland.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1904. *Longden, J. A., M.Inst.C.E. Stanton-by-Dale, near Nottingham.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1901. ‡Longe, Francis D. The Alders, Marina, Lowestoft.
1898. *Longfield, Miss Gertrude. High Halstow Rectory, Rochester.
1901. *Longstaff, Frederick V., F.R.G.S. Ridgelands, Wimbledon, Surrey.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1899. *Longstaff, Tom G., B.A., F.R.Met.Soc. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Sir Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1903. ‡Loton, John, M.A. 23 Hawkshead-street, Southport.
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *LOUIS, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, M.A., Professor of Mining in the Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., D.Sc., F.R.S., Professor of Natural Philosophy in the University of Oxford. 34 St. Margaret's-road, Oxford.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1904. *Love, J. B. Outlands, Devonport.
1875. *Lovett, W. Jesse. Panton House, Panton-road, Hoole, Chester.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Spondon, Derbyshire.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1903. *LOWRY, Dr. T. MARTIN. 44 Blenheim-crescent, W.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1901. *Lucas, Keith. Greenhall, Forest Row, Sussex.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.
1889. ‡*Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.*
1891. *Lucovich, Count A. Tyn-y-parc, Whitchurch, near Cardiff.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.

Year of Election.

1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. (Local Sec. 1890.) 102 Park-street, Grosvenor-square, W.
1900. ‡LUPTON, WILLIAM C. Bradford.
1864. *Lutley, John. Brockhampton Park, Worcester.
1898. §Luxmoore, Dr. C. M. University College, Reading.
1903. §Lyddon, Ernest H. Lisvane, near Cardiff.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. 48 Eaton-place, S.W.
1899. ‡Lyle, Professor Thomas R. The University, Melbourne.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. ‡Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. ‡Lyster, A. G. Dockyard, Coburg Dock, Liverpool.
1862. *LYTE, F. MAXWELL, M.A., F.C.S. 60 Finborough-road, S.W.

1868. ‡MACALISTER, ALEXANDER, M.A., M.D., F.R.S. (Pres. H, 1892; Council, 1901–), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1904. §Macalister, Miss M. A. M. Torrisdale, Cambridge.
1896. ‡*Macalister, R. A. S. 2 Gordon-street, W.C.*
1897. ‡McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.
1896. §MACALLUM, Professor A. B., Ph.D. (Local Sec. 1897.) 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander. 79 Holland-park, W.
1896. ‡McArthur, Charles. Villa Marina, New Brighton, Cheshire.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1904. *Macaulay, W. H. King's College, Cambridge.
1896. ‡MACBRIDE, Professor E. W., M.A. McGill University, Montreal, Canada.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1902. *Maccall, W. T., M.Sc. 223 Burrage-road, Plumstead.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Care of Sir Sherston Baker, Bart., 18 Cavendish-road, Regent's Park, N.W.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1904. §McClean, Frank Kennedy. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1902. ‡McClelland, J. A., M.A., Professor of Physics in University College, Dublin.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.

Year of Election.

1878. *M'Comas, Henry. Pembroke House, Pembroke-road, Dublin.
1901. *MacConkey, Alfred. Lister Institute of Preventive Medicine, Chelsea-gardens, S.W.
1901. ‡MacCormac, J. M., M.D. 31 Victoria-place, Belfast.
1892. *McCowan, John, M.A., D.Sc. Henderson-street, Bridge of Allan, N.B.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1901. ‡McCrae, John, Ph.D. 7 Kirklee-gardens, Glasgow.
1904. §McCulloch, Major T., R.A. 68 Victoria-street, S.W.
1899. ‡McDiarmid, Jabez. The Elms, Stanmore, Middlesex.
1904. §Macdonald, H. M., M.A., F.R.S. Clare College, Cambridge.
1900. ‡MacDonald, J. R. 3 Lincoln's Inn-fields, W.C.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn-fields, W.C.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, Sir W. C. 891 Sherbrooke-street, Montreal, Canada.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
1902. ‡Macfadyen, Allan, M.D., B.Sc. Lister Institute of Preventive Medicine, Chelsea-gardens, S.W.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1897. ‡McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1901. ‡Macfee, John. Marguerite, Blackhall, Paisley.
1897. ‡McGaw, Thomas. Queen's Hotel, Toronto, Canada.
1888. ‡MacGeorge, James. 7 Stonor-road, Kensington, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buckingham-terrace, Glasgow.
1902. ‡McIlroy, Archibald. Glenvale, Drumbo, Lisburn, Ireland.
1867. *McIntosh W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D., LL.D., Principal of and Professor of Anatomy in University College, Dundee.
1897. ‡McKay, T. W. G., M.D. Oshawa, Ontario, Canada.
1896. *McKechnie, Duncan. Eccleston Grange, Prescot.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901; Council, 1903-), Professor of Physiology in the University of Glasgow. 2 Buckingham-terrace, Glasgow.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1884. ‡MacKenzie, Stephen, M.D. 18 Cavendish-square, W.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1901. *Mackenzie, Thomas Brown. Calder View, Motherwell.
1883. ‡Mackeson, Henry. Hythe, Kent.
1872. *Mackey, J. A. 175 Grange-road, S.E.

Year of Election.

1867. ‡MACKIE, SAMUEL JOSEPH. 17 Howley-place, W.
1901. §Mackie, William, M.D. 13 North-street, Elgin.
1887. ‡MACKINDER, H. J., M.A., F.R.G.S. (Pres. E, 1895; Council, 1904– .) London School of Economics, Clare Market, W.C.
1891. ‡Mackintosh, A. C. 88 Plymouth-road, Penarth.
1892. ‡Maclagan, Philip R. D. St. Catherine's, Liberton, Midlothian.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.
1885. *M'LAREN, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1894. *McLaren, Mrs. E. L. Colby, M.B., Ch.B. 4 Duke-street, Edinburgh.
1897. ‡MacLaren, J. F. 380 Victoria-street, Toronto, Canada.
1901. ‡Maclaren, J. Malcolm. 62 Sydney-street, South Kensington, S.W.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1897. ‡MacLaren, Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.
1901. ‡Maclay, James. 3 Woodlands-terrace, Glasgow.
1901. ‡Maclay, William. Thornwood, Langside, Glasgow.
1901. §McLean, Angus, B.Sc. Ascog, Meikleriggs, Paisley.
1892. *MACLEAN, MAGNUS, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLEOD, HERBERT, F.R.S. (Pres. B, 1892; Council, 1885-90). 9 Coverdale, Richmond, Surrey.
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1883. ‡MACMAHON, Major PERCY A., R.A., D.Sc., F.R.S. (GENERAL SECRETARY, 1902– ; Pres. A, 1901; Council, 1898–1902.) Queen Anne's-mansions, Westminster, S.W.
1902. ‡McMordie, Robert J. Cabin Hill, Knock, Co. Down.
1884. ‡McMurrick, J. Playfair. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, A. W. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1901. §MacRitchie, David. 4 Archibald-place, Edinburgh.
1902. ‡McWeeney, E. J., M.D. 84 Stephen's-green, Dublin.
1902. §McWhirter, William. 9 Walworth-terrace, Glasgow.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1902. ‡Magill, R., M.A., Ph.D. The Manse, Maghera, Co. Derry.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *MAGNUS, Sir PHILIP, B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. ‡Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
1902. ‡Mahon, J. L. 2 May-street, Drumcondra, Dublin.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1887. ‡*Mainprice, W. S. Longcroft, Altrincham, Cheshire.*
1902. §Maitland, Miss Agnes C. Somerville College, Oxford.
1883. ‡*Maitland, P. C. 136 Great Portland-street, W.*
1899. ‡Makarius, Saleem. 'Al Mokattam,' Cairo.
1881. ‡*Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.*
1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.

Year of
Election.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1897. ‡MANCE, Sir H. C. 32 Earl's Court-square, S.W.
1887. ‡MANCHESTER, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1903. §Manifold, C. C. 16 St. James's-square, S.W.
1901. ‡Mann, John, jun., M.A. 137 West George-street, Glasgow.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1888. ‡MANSERGH, JAMES, M.Inst.C.E., F.R.S., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1902. *Marchant, Dr. E. W. University College, Liverpool.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1900. ‡Margerison, Samuel. Calverley Lodge, near Leeds.
1887. ‡*Margetson, J. Charles. The Rocks, Limpley, Stoke.*
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. ‡*Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.*
1864. ‡MARKHAM, Sir CLEMENTS R., K.C.B., F.R.S., Pres.R.G.S., F.S.A. (Pres. E, 1879; Council 1893-96). 21 Eccleston-square, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, J. E., M.A., D.Sc., F.R.S., F.G.S. (Pres. C, 1896; Council 1896-1902). St. John's College, Cambridge.
1903. §Marriott, William. Royal Meteorological Society, 70 Victoria-street, S.W.
1887. ‡*Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.*
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. 72 Wellington-street, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., D.Sc. (Pres. F, 1890), Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1904. §Marshall, F. H. A., D.Sc., F.R.S. University of Edinburgh.
1892. ‡Marshall, Hugh, D.Sc., F.R.S., F.R.S.E. 12 Lonsdale-terrace, Edinburgh.
1890. ‡Marshall, John. Derwent Island, Keswick.
1901. §Marshall, Robert. 97 Wellington-street, Glasgow.
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. ‡MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1891. *Martin, Edward P., J.P. The Hill, Abergavenny, Monmouthshire.
1887. **Martin, Rev. H. A. Grosvenor Club, Grosvenor-crescent, S.W.*
1884. §Martin, N. H., J.P., F.L.S. Ravenswood, Low Fell, Gateshead-on-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.

Year of Election.

1883. ‡MARWICK, Sir J. D., LL.D., F.R.S.E. (Local Sec. 1871, 1876, 1901.) Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1873. *MASHAM, Lord. Swinton Park, Swinton.
1847. ‡MASKELYNE, NEVIL STORY, M.A., D.Sc., F.R.S., F.G.S. (Council 1874–80). Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1893. *Mason, Thomas. Endersleigh, Alexandra Park, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc., F.R.S. University of Melbourne, Victoria, Australia.
1898. ‡Masterman, A. T. University of St. Andrews, N.B.
1901. *Mather, G. R. Boxlea, Wellingborough.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, Sir William, M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡*Mathers, J. S. 1 Hanover-square, Leeds.*
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1898. ‡Mathews, E. R. Norris. Cotham-road, Cotham, Bristol.
1894. ‡MATHEWS, G. B., M.A., F.R.S. St. John's College, Cambridge.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1881. ‡Mathwin, Henry, B.A. 26 Oxford-road, Birkdale, Southport.
1883. ‡Mathwin, Mrs. H. 26 Oxford-road, Birkdale, Southport.
1902. ‡Matley, C. A. 90 St. Lawrence-road, Clontarf, Dublin.
1904. *Matthaei, Miss G. L. C. Newnham College, Cambridge.
1904. §Matthews, D. J. The Laboratory. Citadel Hill, Plymouth.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1899. ‡MATTHEWS, WILLIAM, C.M.G., M.Inst.C.E. 9 Victoria-street, S.W.
1893. ‡Mavor, Professor James. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Sir Hiram S. 18 Queen's Gate-place, Kensington, S.W.
1903. ‡Maxwell, J. M. 37 Ash-street, Southport.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1901. *May, W. Page, M.D., B.Sc. 9 Manchester-square, W.
1884. *Maybury, A. C., D.Sc. 8 Heathcote-street, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1904. §Mayo, Rev. J., LL.D. 6 Warkworth-terrace, Cambridge.
1871. ‡Meikle, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C. (Pres. B, 1895; Council 1892–99), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1883. ‡Mellis, Rev. James. 23 Part-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
1883. ‡Mello, Mrs. J. M. Cliff Hill, Warwick.
1896. §Mellor, G. H. Weston, Blundellsands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1901. ‡Mennell, F. P. 8 Addison-road, W.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, E.C.
1879. ‡MERIVALE, JOHN HERMAN, M.A. (Local Sec. 1889). Togston Hall, Acklington.

Year of
Election.

1899. *Merrett, William H. Hatherley, Grosvenor-road, Wallington, Surrey.
1880. ‡*Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.*
1899. ‡Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1896. ‡Metzler, W. H., Professor of Mathematics in Syracuse University Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Local Sec. 1890), Professor of Biology in the University of Leeds. Richmond-mount, Headingley, Leeds.
1903. ‡Micklethwait, Miss F. G. Queen's College, Galway.
1866. ‡*Middlemore, Thomas. Holloway Head, Birmingham.*
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1893. ‡Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 46 Windsor-road, Ealing, W.
1904. §Middleton, T. H., M.A., Professor of Agriculture in the University of Cambridge. South House, Barton-road, Cambridge.
1894. *MIERS, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. ‡MILES, MORRIS (Local Sec. 1882). Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901.) 62 Camden-square, N.W.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1895. ‡Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. ‡Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
1902. ‡Millin, S. T. Sheridan Lodge, Helen's Bay, Co. Down.
1904. §Millis, C. T. Hollydene, Wimbledon Park-road, Wimbledon.
1868. *MILLS EDMUND J., D.Sc., F.R.S., F.C.S. 64 Twyford-avenue, West Acton, W.
1880. ‡Mills, Mansfeldt H., M.Inst.C.E., F.G.S. Sherwood Hall, Mansfield.
1902. ‡Mills, W. Sloan, M.A. Vine Cottage, Donaghmore, Newry.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1903. *Milne, R. M. Royal Military Academy, Woolwich.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1898. *Milner, S. Roslington, D.Sc. University College, Sheffield.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, N.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Cooper's Hill, Surrey.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.

Year of Election.

1901. *Mitchell, Andrew Acworth. 7 Huntly-gardens, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
1901. *Mitchell, G. A. 5 West Regent-street, Glasgow.
1885. ‡Mitchell, P. Chalmers, M.A., D.Sc, Sec.Z.S. 3 Hanover-square, W.
1895. *Moat, William, M.A. Johnson Hall, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1877. *Molloy, Right Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1900. §Monckton, H. W., F.L.S., F.G.S. 3 Harcourt-buildings, Temple, E.C.
1887. *Mond, Ludwig, Ph.D., D.Sc., F.R.S., F.C.S. (Pres. B, 1896.) 20 Avenue-road, Regent's Park, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. ‡Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.
1894. §Moore, Harold E. Oaklands, The Avenue, Beckenham, Kent.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
1901. *Moore, Robert T. 142 St. Vincent-street, Glasgow.
1896. *Mordey, W. M. 82 Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1901. *Moreno, Francisco P. La Plata Museum, Argentina.
1881. ‡Morgan, Alfred. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. ‡Morgan, C. Lloyd, F.R.S., F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 21 Upper Parliament-street, Liverpool.
1902. ‡Morgan, Gilbert T., D.Sc., F.I.C. Royal College of Science, S.W.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1902. *Morgan, Septimus Vaughan. 37 Harrington-gardens, S.W.
1882. ‡Morgan, Thomas, J.P. Cross House, Southampton.
1901. *Morison, James. Perth.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 5 Lyndhurst-road, Hampstead, N.W.
1889. ‡Morley, The Right Hon. John, M.A., LL.D., M.P., F.R.S. Flowermead, Wimbledon Park, Surrey.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Sir Daniel, K.C.M.G., M.A., D.Sc., F.L.S. Barbados, West Indies.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.

Year of Election.

1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1896. *Morris, J. T. 13 Somers-place, W.
1874. ‡Morrison, G. James, M.Inst.C.E. 7 The Sanctuary, Westminster, S.W.
1899. §Morrow, Captain John, M.Sc. 19 Elliston-road, Redland, Bristol.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1858. *Morton, Henry Joseph. 2 Westbourne-villas, Scarborough.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. 15 Ashley-place, Westminster, S.W.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's College, Belfast.
1878. *Moss, John Francis, F.R.G.S. (Local Sec. 1879.) Beechwood, Brincliffe, Sheffield.
1876. §Moss, Richard Jackson, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. St. Hilda's, Frizinghall, Bradford.
1892. *Mostyn, S. G., M.A., M.B. Health Office, South Shields.
1866. ‡Mott, Frederick T., F.R.G.S. Crescent House, Leicester.
1878. *Moulton, J. Fletcher, M.A., K.C., M.P., F.R.S. 57 Onslow-square, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., M.A., F.C.S. Heightley, Chudleigh, Devon.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1899. *Muff, Herbert B. Geological Survey Office, Edinburgh.
1894. ‡*Mugliston, Rev. J., M.A. Newick House, Cheltenham.*
1902. §Muir, Arthur H., C.A. 2 Wellington-place, Belfast.
1874. ‡Muir, M. M. Pattison, M.A. Gonville and Caius College, Cambridge.
1904. §Muir, William. Collector's Office, Custom House, E.C.
1872. *Muirhead, Alexander, D.Sc., F.R.S., F.C.S. 12 Carteret-street, Queen Anne's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., D.Sc. 24 Kersland-street, Hillhead, Glasgow.
1902. ‡Mullan, James. Castlerock, Co. Derry.
1884. *Müller, Hugo, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
1904. §Mullinger, J. Bass, M.A. St. John's College, Cambridge.
1897. ‡Mullins, W. E. Hampstead, N.W.
1898. ‡Mumford, C. E. Bury St. Edmunds.
1901. *Munby, Alan E. 7 Chalcot-crescent, Primrose Hill, N.W.
Munby, Arthur Joseph. 6 Fig Tree-court, Temple, E.C.
1904. §Munro, A. Queen's College, Cambridge.
1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.
1901. ‡Munro, Donald, M.D., J.P. Wheatholm, Pollokshaws, Glasgow.
1898. ‡Munro, John, Professor of Mechanical Engineering in the Merchant Venturers' Technical College, Bristol.

Year of Election.

1883. *MUNRO, ROBERT, M.A., M.D. (Pres. H, 1893). 48 Manor-place, Edinburgh.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., D.Sc., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899.) Challenger Lodge, Wardie, Edinburgh.
1884. ‡Murray, J. Clark, LL.D. 111 McKay-street, Montreal, Canada.
1903. ‡Murray, J. D. Rowbottom-square, Wigan.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1897. ‡Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1902. ‡Myddleton, Alfred. 62 Duncairn-street, Belfast.
1902. *Myers, Charles S., M.A., M.D. 62 Holland-park, W.
1890. *MYRES, JOHN L., M.A., F.S.A. 1 Norham-gardens, Oxford.

1886. ‡NAGEL, D. H., M.A. (Local Sec. 1894.) Trinity College, Oxford.
1892. *Nairn, Sir Michael B., Bart. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 34 Queen-street, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U.S.A.
1896. ‡Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel-walks, Manchester.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1887. ‡*Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.*
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1897. ‡Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1898. §Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. §NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1889. *Newall, H. Frank, M.A., F.R.S., F.R.A.S. Madingley Rise, Cambridge.
1901. §Newbigin, Miss Marion, D.Sc. 1 Greenbank-road, Morningside, Edinburgh.
1886. ‡Newbolt, F. G. Oakley Lodge, Weybridge, Surrey.
1901. ‡Newman, F. H. Tullie House, Carlisle.
1889. ‡Newstead, A. H. L., B.A. 38 Green-street, Bethnal Green, N.E.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S. (Pres. D, 1887; Council 1875–82), Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1867. ‡Nicholl, Thomas. Dundee.
1887. *Nicholson, John Carr, J.P. Moorfield House, Headingley, Leeds.

Year of Election.

1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887 ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1901. ‡NICOL, JAMES, City Chamberlain. Glasgow.
1885. ‡Nicol, W. W. J., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. ‡Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Old Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.
1863. *NOBLE, Sir ANDREW, Bart., K.C.B., D.Sc., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Council, 1903– ; Local Sec. 1863.) Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1879. ‡Noble, T. S. Lendal, York.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895.) Constitution Hill, Ipswich.
1903. ‡Noton, John. 45 Part-street, Southport.
Nowell, John. Farnley Wood, near Huddersfield.
1896. ‡Nugent, the Right Rev. Monsignor. Harewood House, Formby, Lancashire.

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council 1865–70), Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1894. §Ogden, James. Kilner Deyne, Rochdale.
1902. §Ogden, James Neal. Claremont, Heaton Chapel, Stockport.
1896. ‡*Ogden, Thomas. 4 Prince's-avenue, Liverpool.*
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. (Local Sec. 1892.) Board of Education, S.W.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Duffield-road, Derby.
1884. ‡O'Halloran, J. S., C.M.G. Royal Colonial Institute, Northumberland-avenue, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1896. ‡Oldham, G. S. Town Hall, Birkenhead.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.

Year of Election.

1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. *OLDHAM, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., 9 Pall Mall, S.W.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. 2 The Vale, Chelsea, S.W.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.L.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1902. ‡O'Neill, Henry, M.D. 6 College-square East, Belfast.
1902. ‡O'Neill, James, M.A. 5 College-square East, Belfast.
1872. ‡*Onslow, D. Robert. New University Club, St. James's, S.W.*
1883. ‡Oppert, Gustav, Professor of Sanskrit in the University of Berlin
1902. ‡O'Reilly, Patrick Joseph. 7 North Earl-street, Dublin.
1899. ‡Orling, Axel. Moorgate Station-chambers, E.C.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. St. Leonard's, Kilkenny, Co. Dublin.
1884. *Orpen, Lieut.-Colonel R. T., R.E. Monksgrange, Enniscorthy, Co. Wexford.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1901. §Orr, Alexander Stewart. Care of Messrs. Marsland, Price, & Co., Nesbit-road, Mazagon, Bombay, India.
1904. *Orton, K. J. P., M.A., Ph.D., Professor of Chemistry in University College, Bangor.
1899. ‡Osborn, Dr. F. A. The Châlet, Dover.
1897. ‡Osborne, James K. 40 St. Joseph-street, Toronto, Canada.
1901. ‡Osborne, W. A., D.Sc. University College, W.C.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
1897. ‡Osler, E. B., M.P. Rosedale, Toronto, Canada.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, WILLIAM, M.D., LL.D., F.R.S., Regius Professor of Medicine in the University of Oxford.
1884. ‡*O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.*
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1903. *Owen, Edwin, M.A. Terra Nova, Birkdale, Lancashire.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester.

1903. *Page, Miss Ellen Iva. Turret House, Felpham, Sussex.
1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1898. ‡Paget, The Right Hon. Sir R. H., Bart. Cranmore Hall, Shepton Mallet.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F, 1883.) Belton, Great Yarmouth.

Year of Election.

1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1904. §PARKER, E. H., M.A. Thorneycreek, Herschel-road, Cambridge.
1898. ‡Parker, G., M.D. 14 Pembroke-road, Clifton, Bristol.
1903. §Parker, Rev. J. Dunne, LL.D., D.C.L., F.R.A.S. Bennington House, viâ Stevenage, Hertfordshire.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1899. ‡*Parker, Mark. 30 Upper Fant-road, Maidstone.*
1891. ‡PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1899. *Parkin, John. Blaithwaite, Carlisle.
1879. *Parkin, William. The Mount, Sheffield.
1887. ‡Parkinson, James. Greystones, Langho, Blackburn.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1903. §Parry, Joseph, M.Inst.C.E. Woodbury, Waterloo-road, Liverpool.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1878. ‡PARSONS, Hon. C. A., C.B., M.A., D.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1904.) Holeyn Hall, Wylam-on-Tyne.
1904. §Parsons, Professor F. G. St. Thomas's Hospital, S.E.
1898. *Partridge, Miss Josephine M. 15 Grosvenor-crescent, S.W.
1898. ‡Pass, Alfred C. Clifton Down, Bristol.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in the University of Liverpool.
1897. ‡Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896. ‡Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1897. ‡Paton, D. Noël, M.D. 22 Forrest-road, Edinburgh.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth-terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1902. ‡Patterson, Robert, F.Z.S., M.R.I.A. Ivy Dene, Malone Park, Belfast.
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1883. ‡Paul, George. 10 St. Mary's-avenue, Harrogate.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles, J.P. Albion-place, The Plains, Belfast.
1881. ‡Payne, Mrs. Albion-place, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1875. †Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.

Year of Election.

1886. *Pearce, Mrs. Horace. Orsett House, Birmingham-road, Kidderminster.
1886. ‡*Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.*
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. §Pearson, George. Bank-chambers, Baldwin-street, Bristol.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1904. §Pearson, Karl, M.A., F.R.S., Professor of Applied Mathematics in University College, London, W.C.
1881. ‡Pearson, Richard. 57 Bootham, York.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡*Peddie, William, D.Sc., F.R.S.E. 2 Cameron-park, Edinburgh.*
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. Summerslea, Lingfield, Surrey.
1901. *Peel, Hon. William, M.P. 13 King's Bench-walk, Temple, E.C.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
1887. ‡Pendlebury, William H., M.A., F.C.S. (Local Sec. 1899.) Woodford House, Mountfields, Shrewsbury.
1894. §Pengelly, Miss. Lamorna, Torquay.
1897. ‡Penhallow, Professor D. P., M.A. McGill University, Montreal, Canada.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Pentecost, Rev. Harold, M.A. The School, Giggleswick, Yorkshire.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 2 Southwick-place, W.
1895. ‡Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Chalcots, Lower Kingswood, Reigate.
1894. ‡Perkin, A. G., F.R.S., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1902. §Perkin, F. Mollwo, Ph.D. The Firs, Hengrave-road, Honor Oak Park, S.E.
1868. *Perkin, William Henry, Ph.D., LL.D., D.Sc., F.R.S., F.C.S. (Pres. B, 1876; Council 1880–86). The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council 1901–), Professor of Organic Chemistry in the Owens College, Manchester. Fairview, Wilbraham-road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P., D.Sc. University College, Cardiff.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.
1874. *Perry, John, M.E., D.Sc., F.R.S. (General Treasurer, 1904– ; Pres. G, 1902; Council 1901–04), Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.

Year of Election.

1904. *Pertz, Miss D. F. M. 2 Cranmer-road, Cambridge.
1900. §Petavel, J. E. The Owens College, Manchester.
1897. ‡Peters, Dr. George A. 171 College-street, Toronto, Canada.
1898. ‡Pethick, William. Woodside, Stoke Bishop, Bristol.
1901. ‡Pethybridge, G. H. Museum of Science and Art, Dublin.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. ‡PETRIE, W. M. FLINDERS, D.C.L., F.R.S. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Hove, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton terrace, Oakley-street, S.W.
1896. ‡Philip, George, jun. Weldon, Bidston, Cheshire.
1903. ‡Philip, James C. 20 Westfield-terrace, Aberdeen.
1892. ‡Philip, R. W. M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, Crescent-road, South Woodford, Essex.
1863. ‡Philipson, Sir G. H. 7 Eldon-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1899. *Phillips, Charles E. S. Castle House, Shooter's Hill, Kent.
1894. ‡Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡*Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.*
1902. ‡Phillips, J. St. J., B.E. 64 Royal-avenue, Belfast.
1890. ‡Phillips, R. W., M.A., D.Sc., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1898. ‡Philps, Captain Lambe. 7 Royal-terrace, Weston-super-Mare.
1884. *Pickard, Rev. H. Adair, M.A. Airedale, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Isca, Merlin-road, Blackburn.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1865. ‡PIKE, L. OWEN. 4A Marlborough-gate, Hyde Park, W.
1873. ‡Pike, W. H., M.A., Ph.D. Toronto, Canada.
1896. *Pilkington, A. C. Rocklands, Rainhill, Lancashire.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡*Pinder, T. R. St. Andrew's, Norwich.*
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡*Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, Borough, S.E.*
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, E.C.
1893. *PITT, WALTER, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Fairmount, Bingley.
1898. ‡Playne, H. C. 28 College-road, Clifton, Bristol.
1893. ‡Plowright, Henry J. Ashdown House, Fawley, near Southampton.

Year of Election.

1897. ‡Plummer, J. H. Bank of Commerce, Toronto, Canada.
1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1899. ‡Plumptre, Fitzwalter. Goodnestone, Dover.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Queen's Co., Ireland.
1900. *Pocklington, H. Cabourn. 41 Virginia-road, Leeds.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡*Pocock, Rev. Francis. 4 Brunswick-place, Bath.*
1896. ‡Pollard, James. High Down, Hitchin, Herts.
1904. §Pollard, William. 12 Aberdare-gardens, Hampstead, N.W.
1898. ‡*POLLEN, Rev. G. C. H., F.G.S. Stonyhurst College, Blackburn.*
1896. *Pollex, Albert. Tenby House, Egerton Park, Rockferry.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1900. §POPE, W. J., F.R.S., Professor of Chemistry in the Municipal School of Technology, Manchester. 16 Hope-street, Higher Broughton, Manchester.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. The Yew, Marple, near Stockport.
1868. ‡PORTAL, Sir WYNDHAM S., Bart. Malshanger, Basingstoke.
1901. §Porter, Alfred W., B.Sc. 87 Parliament Hill-mansions, Lissenden-gardens, N.W.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. University College, Gower-street, W.C.
1887. ‡*Potter, Edmund P. Hollinhurst, Bolton.*
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Highbury, Newcastle-upon-Tyne.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council 1895–1901), Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs, F.R.G.S. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Brynmill-crescent, Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, Cavendish-square, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. 20 Birchin-lane, E.C.
1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡POYNTING, J. H., D.Sc., F.R.S. (Pres. A, 1899), Professor of Physics in the University of Birmingham. 10 Ampton-road, Edgbaston, Birmingham.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888; Council 1888–95, 1896–1902.) Gothic Lodge, Wimbledon Common, Surrey; and 8 Queen Anne's-gate, S.W.
1888. *Preece, W. Llewellyn. Bryn Helen, Woodborough-road, Putney, S.W.
1904. §Prentice, Mrs. Manning. Thelema, Felixstowe.
1892. §Prentice, Thomas. Willow Park, Greenock.

Year of Election.

1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 48 Ropewalk, Nottingham.
1884. *Prevost, Major L. de T., 2nd Battalion Argyll and Sutherland Highlanders.
1903. §Price, Edward E. Oaklands, Oaklands-road, Bromley, Kent.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898–1904.) Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1897. *PRICE, W. A., M.A. The Mill House, Broomfield, Chelmsford.
1897. ‡Primrose, Dr. Alexander. 196 Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel-gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. 79 Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 100 State-street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1903. §Pullen-Burry, Miss. Care of Mrs. Kilvington, Coniston, Avondale-road, South Croydon.
1887. §PUMPHREY, WILLIAM. (Local Sec. 1888.) 2 Oakland-road, Redland, Bristol.
1904. §Punnett, R. C. Caius College, Cambridge.
1885. ‡PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines Castle, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., LL.D., M.R.I.A. (Pres. A, 1902.) Rathmines Castle, Dublin.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. ‡Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor W. J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.

Year of Election.

1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Stand, near Manchester.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh. The Technical Institute, Norwich.
1894. *Rambaut, Arthur A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1863. ‡Ramsay, Alexander. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *Ramsay, Sir William, K.C.B., Ph.D., F.R.S. (Pres. B, 1897; Council 1891–98), Professor of Chemistry in University College, London. 19 Chester-terrace, Regent's Park, N.W.
1883. ‡Ramsay, Lady. 19 Chester-terrace, Regent's Park, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, W.
1901. ‡Rankin, James, M.A., B.Sc. The University, Glasgow.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. (Local Sec. 1861.) Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. ‡Rapkin, J. B. Thrale Hall, Streatham, S.W.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1903. §Rastall, R. H. Christ's College, Cambridge.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1874. ‡Ravenstein, E. G., F.R.G.S., F.S.S. (Pres. E, 1891.) 2 York-mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1868. *Rayleigh, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (President, 1884; Trustee, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. ‡Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree, M.A. 19 Tiviot Dale, Stockport.
1896. *Read, Charles H., F.S.A. (Pres. H, 1899). British Museum, W.C.
1902. ‡Reade, R. H. Wilmount, Dunmurry.
1870. ‡Reade, Thomas Mellard, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1899. †Reaster, James William. 68 Linden-grove, Nunhead, S.E.
1852. *Redfern, Professor Peter, M.D. (Pres. D, 1874.) 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. Wadham Lodge, Wadham-gardens, N.W.

Year of Election.

1861. ‡REED, Sir EDWARD JAMES, K.C.B., F.R.S. Broadway-chambers, Westminster, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1891. *Rees, I. Treharne, M.Inst.C.E. Blaenypant, near Newport, Monmouthshire.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897. ‡Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1903. §Reeves, E. A., F.R.G.S. 1 Savile-row, W.
1901. *Reid, Andrew T 10 Woodside-terrace, Glasgow.
1904. §Reid, Arthur H. P.O. Box 120, Cape Town.
1881 §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1903. *Reid, Mrs. E. M., B.Sc. 36 Sarre-road, West Hampstead, N.W.
1892. ‡REID, E. WAYMOUTH, B.A., M.B., F.R.S., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1901. *Reid, Hugh. Belmont, Springburn, Glasgow.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1901. ‡Reid, John. 7 Park-terrace, Glasgow.
1904. §Reid, P. J. German Cottage, Marske-by-the-Sea.
1897. §Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1893. ‡Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875. ‡REINOLD, A. W., M.A., F.R.S. (Council 1890–95), Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1894. ‡RENDALL, Rev. G. H., M.A., Litt.D. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1903. §RENDLE, Dr. A. B., M.A., F.L.S. 47 Wimbledon Park-road, Wimbledon.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1904. §REUNERT, THEODORE, M.Inst.CE. (VICE-PRESIDENT, 1905.) P.O. Box 92, Johannesburg.
1883. *Reynolds, A. H. Bank House, 135 Lord-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., Pres.C.S., M.R.I.A. (Pres. B, 1893; Council 1893-99). 29 Campden Hill-court, W.
1900. *Reynolds, Miss K. M. 4 Colinette-road, Putney, S.W.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1887), Professor of Engineering in the Owens College, Manchester. 19 Lady Barn-road, Fallowfield, Manchester.
1896. ‡Rhodes, Albert. Fieldhurst, Liversidge, Yorkshire.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1890. ‡Rhodes, J. M., M D. Ivy Lodge, Didsbury.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1899. *RHYS, Professor JOHN, D.Sc. (Pres. H, 1900). Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro, 14, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.

Year of Election.

1869. *Richardson, Charles. 3 Cholmley-villas, Long Ditton, Surrey.
1882. ‡Richardson, Rev. George, M.A. Walcote, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh, M.A. Bootham School, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willans. Trinity College, Cambridge.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886. ‡Richmond, Robert. Heathwood, Leighton Buzzard.
1883. *Rideal, Samuel, D.Sc., F.C.S. 28 Victoria-street, S.W.
1902. §Ridgeway, William, M.A., Professor of Archæology in the University of Cambridge. Fen Ditton, Cambridge.
1894. §Ridley, E. P., F.G.S. (Local Sec. 1895.) Burwood, Westerfield-road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1881. *Rigg, Arthur. 15 Westbourne Park-villas, W.
1883. *Rigg, Edward, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
*Ripon, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1903. *Rivers, W. H. R., M.D. St. John's College, Cambridge.
1900. ‡Rixon, F. W., B.Sc. 79 Green-lane, Heywood, Lancashire.
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1902. *Roberts, Bruno. 30 St. George's-square, Regent's Park, N.W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
1859. ‡Roberts, George Christopher. Hull.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 4 Regent-street, Cambridge.
1879. ‡Roberts, Samuel, M.P. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 33 Serpentine-road, Liscard, Cheshire.
1904. *Robertson, Miss Agnes. 9 Elsworthy-terrace, Primrose Hill, N.W.
1883. ‡Robertson, Alexander. Montreal, Canada.
1884. ‡*Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.*
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1897. §Robertson, Sir George S., K.C.S.I. (Pres. E, 1900.) 1 Pump-court, Temple, E.C.
1897. §Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. 154 West George-street, Glasgow.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1886. **Robinson, C. R. 27 Elvetham-road, Birmingham.*
1898. §Robinson, Charles E., M.Inst.C.E. Holm Cross, Ashburton, South Devon.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1903. §Robinson, G. H. 1 Weld-road, Southport.
1897. ‡Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, S.W.

Year of Election.

1902. ‡Robinson, Herbert C. Holmfield, Aigburth, Liverpool.
1902. ‡Robinson, James, M.A., F.R.G.S. Dulwich College, Dulwich, S.E.
1901. §Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1899. *Robinson, Mark, M.Inst.C.E. 9 Belsize-grove, N.W.
1887. ‡Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1901. ‡Robinson, T. Eaton. 33 Cecil-street West, Glasgow.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1904. §Robinson, Theodore R. 25 Campden Hill-gardens, W.
1904. §Robinson, W. H. Ribblesdale, Cardiff-road, Llandaff.
1891. ‡Robinson, William, M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡*Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, N.W.*
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. E. S. Talbot, D.D., Lord Bishop of. Kennington Park, S.E.
1896. ‡*Rock, W. H. 73 Park-road East, Birkenhead.*
1896. ‡Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert-street, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. ‡Rogers, Bertram, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1890. *Rogers, L. J., M.A., Professor of Mathematics in the University of Leeds. 15 Regent Park-avenue, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Canon Saltren, M.A. 15 Somerset-place, Bath.
1884. *Rogers, Walter. Hill House, St. Leonard's.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1897. ‡Rogerson, John. Barrie, Ontario, Canada.
1876. ‡Rollit, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. 45 Belgrave-square, S.W.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1881. *Roper, W. O. Beechfield, Yealand Conyers, Carnforth.
1855. *Roscoe, Sir Henry Enfield, B.A., Ph.D., LL.D., D.C.L., F.R.S. (President, 1887; Pres. B, 1870, 1884; Council 1874-81; Local Sec. 1861.) 10 Bramham-gardens, S.W.
1883. *Rose, J. Holland, Litt.D. 11 Endlesham-road, Balham, S.W.
1894. *Rose, T. K., D.Sc, Chemist and Assayer to the Royal Mint. Royal Mint, E.
1900. ‡Rosenhain, Walter, B.A. 185 Monument-road, Edgbaston, Birmingham.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1887. ‡Ross, Edward. Marple, Cheshire.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1902. §Ross, John Callender. 46 Holland-street, Campden Hill, W.
1901. ‡Ross, Major Ronald, C.B., F.R.S., Professor of Tropical Medicine and Parasitology in the University of Liverpool. 36 Bentley-road, Liverpool.

Year of Election.

1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. *Roth, H. Ling. 32 Prescot-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell. Hazlewood, Forest-grove, Nottingham.
1901. *Rottenburg, Paul, LL.D. Care of Messrs. Leister, Bock, & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1884. *Rouse, M. L. Hollybank, Hayne-road, Beckenham.
1901. ‡Rouse, W. H. D. Perse School, Cambridge.
1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1903. *Rowe, Arthur W., M.B., F.G.S. 1 Cecil-street, Margate.
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *ROWNTREE, JOHN S. Mount-villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1899. ‡Rubie, G. S. Belgrave House, Folkestone-road, Dover.
1875. *RÜCKER, Sir A. W., M.A., D.Sc., F.R.S., Principal of the University of London. (PRESIDENT, 1901; TRUSTEE, 1898– ; GENERAL TREASURER, 1891–98; Pres. A, 1894; Council 1888–91.) 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §RUDLER, F. W., F.G.S. 18 St. George's-road, Kilburn, N.W.
1901. *Rudorf, C. C. G., Ph.D., B.Sc. 26 Weston-park, Crouch End, N.
1904. §Ruhemann, Dr. S. 3 Selwyn-gardens, Cambridge.
1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
1887. ‡*Ruscoe, John. Ferndale, Gee Cross, near Manchester.*
1904. §Russell, E. J., D.Sc., Professor of Chemistry in the South-Eastern Agricultural College, Wye, Kent.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡*Russell, George. 13 Church-road, Upper Norwood, S.E.*
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, Sir J. A., LL.D. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 131 Woodstock-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Dover-street, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., V.P.C.S. (Pres. B, 1873; Council 1873–80). 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897. ‡Rutherford, A. Toronto, Canada.
1891. ‡*Rutherford, George. Dulwich House, Pencisely-road, Cardiff.*
1887. ‡*Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.*
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1897. ‡Ryerson, G. S., M.D. Toronto, Canada.
1898. §Ryland, C. J. Southerndon House, Clifton, Bristol.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.

1903. ‡Sadler, M. E., LL.D., Professor of Education in the Victoria University, Manchester.

Year of Election.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, E.C.
1903. §Sagar, J. The Poplars, Savile Park, Halifax.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1904. §Salter, A. E., D.Sc., F.G.S. 20 Shell-road, Loampit Hill, Lewisham, S.E.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1901. §Samuel, John S., J.P., F.R.S.E. City Chambers, Glasgow.
1894. ‡SAMUELSON, The Right Hon. Sir BERNHARD, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, S.W.
1883. ‡Sanderson, Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §SANDERSON, Sir J. S. BURDON, Bart., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E. (PRESIDENT, 1893; Pres. D, 1889; Council 1877–84). 64 Banbury-road, Oxford.
1883. ‡Sanderson, Lady Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. Tylehurst, Kirkcaldy, Fife.
1903. ‡Sankey, Captain H. R., R.E. Bawmore, Bilton, Rugby.
1886. §Sankey, Percy E. 44 Russell-square, W.C.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. ‡Sargant, W. L. Quarry Hill, Reigate.
1901. ‡Sarruf, N. Y. 'Al Mokattam,' Cairo.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1900. *Saunder, S. A. Fir Holt, Crowthorne, Berks.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1903. *Saunders, Miss E. R. Newnham College, Cambridge.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield-on-the-Knowles, Newton Abbot, Devon.
1884. ‡SAUNDERS, Dr. WILLIAM. Experimental Farm, Ottawa, Canada.
1891. ‡*Saunders, W. H. R. Llanishen, Cardiff.*
1887. ‡Savage, Rev. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, Douglas, Isle of Man.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1901. ‡Sawers, W. D. 1 Athole Gardens-place, Glasgow.
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1903. §SCARISBRICK, Sir CHARLES, J.P. Scarisbrick Lodge, Southport.
1903. ‡Scarisbrick, Lady. Scarisbrick Lodge, Southport.
1879. *SCHÄFER, E. A., LL.D., F.R.S., M.R.C.S. (GEN. SEC. 1895–1900; Pres. I, 1894; Council 1887–93), Professor of Physiology in the University of Edinburgh.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.

Year of Election.

1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)

1892. ‡*Schloss, David F. 1 Knaresborough-place, S.W.*

1887. ‡*Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.*

1883. ‡Schofield, William. Alma-road, Birkdale, Southport.

1885. §Scholes, L. Arncliffe, Trinity-road, Sale, Cheshire.

1873. *Schuster, Arthur, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892; Council 1887–93), Professor of Physics in the Victoria University, Manchester. Kent House, Victoria Park, Manchester.

1847. *Sclater, Philip Lutley, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S. (General Secretary 1876–81; Pres. D, 1875; Council 1864–67, 1872–75.) Odiham Priory, Winchfield.

1883. *Sclater, W. Lutley, M.A., F.Z.S. South African Museum, Cape Town.

1867. ‡Scott, Alexander. Clydesdale Bank, Dundee.

1881. *Scott, Alexander, M.A., D.Sc., F.R.S., Sec.C.S. Royal Institution, Albemarle-street, W.

1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.

1881. ‡Scott, Miss Charlotte Angas, D.Sc. Bryn Mawr College, Pennsylvania, U.S.A.

1889. *Scott, D. H., M.A., Ph.D., F.R.S., F.L.S. (General Secretary, 1900–03; Pres. K, 1896.) The Old Palace, Richmond, Surrey.

1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.

1857. *Scott, Robert H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.

1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.

1902. §Scott, William R. The University, St. Andrew's, Scotland.

1895. ‡Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Ainslea, Scotstounhill, Glasgow.

1883. ‡Scrivener, Mrs. Haglis House, Wendover.

1895. §Scull, Miss E. M. L. The Pines, 10 Langland-gardens, Hampstead, N.W.

1890. *Searle, G. F. C., M.A. Wyncote, Hills-road, Cambridge.

1859. ‡Seaton, John Love. The Park, Hull.

1880. ‡Sedgwick, Adam, M.A., F.R.S. (Pres. D, 1899.) 4 Cranmer-road, Cambridge.

1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, W.

1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.

1893. ‡Selby-Bigge, L. A., M.A. Charity Commission, Whitehall, S.W.

1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.

1879. ‡Selim, Adolphus. 21 Mincing-lane, E.C.

1904. §Sell, W. J. 19 Lensfield-road, Cambridge.

1904. §Sella, Professor Alfonso. Istituto Fisico, Rome.

1897. ‡Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.

1885. ‡Semple, Dr. A. United Service Club, Edinburgh.

1888. *Senier, Alfred, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.

1888. *Sennett, Alfred R., A.M.Inst.C.E. 304 King's-road, Chelsea, S.W.

1901. ‡Service, Robert. Janefield Park, Maxwelltown, Dumfries.

1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.

1892. ‡Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.

Year of Election.

1895. *Seton-Karr, H. W. 31 Lingfield-road, Wimbledon, Surrey.
1892. *SEWARD, A. C., M.A., F.R.S., F.G.S. (Pres. K, 1903; Council, 1901– ; Local Sec. 1904.) Westfield, Huntingdon-road, Cambridge.
1891. ‡*Seward, Edwin. 55 Newport-road, Cardiff.*
1868. ‡Sewell, Philip E. Catton, Norwich.
1904. §Sewell, R. B. Seymour. Christ's College, Cambridge.
1899. §Seymour, Henry J., B.A., F.G.S. St. Peter's, Ailesbury-road, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡*Shackles, Charles F. Hornsea, near Hull.*
1904. §Shackleton, Ernest H. Royal Scottish Geographical Society, Edinburgh.
1902. ‡SHAFTESBURY, The Right Hon. the Earl of, D.L. Belfast Castle, Belfast.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1904. §Sharp, Mrs. E. M. Drumna House, Whetstone, N.
1886. ‡*Sharp, T. B. French Walls, Birmingham.*
1904. §Sharp, Walter. Drumna House, Whetstone, N.
1883. ‡Sharples, Charles H. 7 Fishergate, Preston.
1904. §Sharples, George. 181 Great Cheetham-street West, Higher Broughton, Manchester.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. ‡Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Sydenham Damard Rectory, Tavistock.
1883. *SHAW, W. N., M.A., D.Sc., F.R.S. (Council 1895-1900, 1904– .) Meteorological Office, Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton-gardens, South Kensington, S.W.
1904. §Shaw-Phillips, Miss. 19 Camden-crescent, Bath.
1903. §Shaw-Phillips, T., J.P. 19 Camden-crescent, Bath.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1878. ‡Shelford, Sir William, K.C.M.G., M.Inst.C.E. 35A Great George-street, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A., F.R.S. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1890. ‡Shepherd, J. 80 Prince of Wales-mansions, Battersea, S.W.
1883. ‡Shepherd, James. Birkdale, Southport.
1900. §Sheppard, Thomas, F.G.S. The Municipal Museum, Hull.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1896. §SHERRINGTON, C. S., M.D., F.R.S. (Pres. I, 1904), Professor of Physiology in the University of Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A., F.S.A. St. John's Hospital, Bath
1886. ‡Shield, Arthur H. 35A Great George-street, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland
1901. ‡Shields, Thomas, M.A., B.Sc. Englefield Green, Surrey.
1902. *Shillington, T. Foulkes, J.P. Dromart, Antrim-road, Belfast.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
1887. *SHIPLEY, ARTHUR E., M.A., F.R.S. (Council 1904– .) Christ's College, Cambridge.

Year of
Election.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *Shoolbred, J. N., B.A., M.Inst.C.E. 47 Victoria-street, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, W.C.
1897. ‡Shore, Dr. Lewis E. St. John's College, Cambridge.
1875. ‡Shore, Thomas W., F.G.S. 157 Bedford-hill, Balham, S.W.
1882. ‡Shore, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Heathfield, Alleyn Park, Dulwich, S.E.
1901. §Short, Peter M., B.Sc. 1 Holmdene-avenue, Herne Hill, S.E.
1897. ‡Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.
1904. *Shrubsall, F. C., M.A., M.D. Brompton Hospital, S.W.
1889. ‡Sibley, Walter K., B.A., M.B. 8 Duke Street-mansions, Grosvenor-square, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1902. ‡Siddons, A. W. Harrow-on-the-Hill, Middlesex.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1873. *Siemens, Alexander, M.Inst.C.E. 12 Queen Anne's-gate, S.W.
1903. *Silberrad, Dr. Oswald. Experimental Establishment, Royal Arsenal, Woolwich.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1898. ‡Simmons, Henry. Kingsland House, Whiteladies-road, Clifton, Bristol.
1862. ‡Simms, James. 138 Fleet-street, E.C.
1874. ‡Simms, William. Upper Queen-street, Belfast.
1876. ‡*Simon, Frederick. 24 Sutherland-gardens, W.*
1901. ‡Simpson, Rev. A., B.Sc., F.G.S. 28 Myrtle-park, Crosshill, Glasgow.
1871. *Simpson, Alexander R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1901. *Simpson, J. Y., M.A., D.Sc., F.R.S.E. 52 Queen-street, Edinburgh.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
1896. *Simpson, W., F.G.S. Catteral Hall, Settle, Yorkshire.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Right Hon. Thomas (Local Sec. 1874). Dunedin, Belfast.
1897. ‡Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. ‡Sisley, Richard, M.D. 1 Park-row, S.W.
1902. §Skeffington, J. B., M.A., LL.D. Waterford.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1898. §Skinner, Sidney, M.A. (Local Sec. 1904.) South-Western Polytechnic, Manresa-road, Chelsea, S.W.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S. 65 Pembroke-road, Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.

Year of
Election.

1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., B.Sc., F.G.S. The Mount, Radbourne-street, Derby.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1903. *Smallman, Raleigh S. Wressil Lodge, Wimbledon Common.
1904. §Smart, Edward. Benview, Craigie, Perth, N.B.
1889. *SMART, Professor William, LL.D. (Pres. F, 1904.) Nunholme, Dowanhill, Glasgow.
1902. §Smedley, Miss Ida. 11 Mecklenburgh-square, W.C.
1898. ‡Smeeth, W. F., M.A., F.G.S. Mysore, India.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡*Smethurst, Charles. Palace House, Harpurhey, Manchester.*
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago Illinois, U.S.A.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorrain. 20 Talgarth-road, West Kensington, W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Kodaikanal, South India.
1886. ‡*Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.*
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, S.W.
1897. ‡Smith, Sir Frank. 54 King-street East, Toronto, Canada.
1901. §Smith, F. B. Care of A. Croxton Smith, Esq., Burlington House, Wandle-road, Upper Tooting, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1885. ‡Smith, Rev. G. A., M.A. 22 Sardinia-terrace, Glasgow.
1897. ‡Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 25 Welbeck-street, Cavendish-square, W.
1903. *Smith, H. B. Lees. 16 Park-terrace, Oxford.
1870. ‡*Smith, H. L. Crabwall Hall, Cheshire.*
1889. *Smith, H. Llewellyn, C.B., B.A., B.Sc., F.S.S. 49 St. George's-square, S.W.
1888. ‡Smith, H. W. Owens College, Manchester.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
1902. ‡Smith, J. Lorrain, M.D., Professor of Pathology in the Victoria University, Manchester.
1901. ‡SMITH, Right Hon. J. PARKER, M.P. Jordanhill, Glasgow.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1903. §Smith, James. Pinewood, Crathes, Aberdeen.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance-buildings, Crossley-street, Halifax.
1885. ‡*SMITH, ROBERT H., Assoc.M.Inst.C.E. Ellerslie, Sutton, Surrey.*

Year of Election.

1873. ‡Smith, Sir Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1894. §Smith, T. Walrond. Care of Frank Henderson, Esq., 25 Pearfield-road, Forest Hill, S.E.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. 34 Upper Park-road, Haverstock Hill, N.W.
1896. *Smith, Rev. W. Hodson. Newquay, Cornwall.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡SMITHELLS, ARTHUR, B.Sc., F.R.S. (Local Sec. 1890), Professor of Chemistry in the University of Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1882. ‡Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D. Balholm, Lathom-road, Southport.
1889. ‡Snell, W. H. Lancaster Lodge, Amersham-road, Putney, S.W.
1898. ‡Snook, Miss L. B. V. 13 Clare-road, Cotham, Bristol.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council 1900-03), Professor of Geology in the University of Oxford. 173 Woodstock-road, Oxford.
1892. *SOMERVAIL, ALEXANDER. The Museum, Torquay.
1900. *SOMERVILLE, W., D.Sc. Board of Agriculture, Whitehall, S.W.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. (Pres. C, 1880; Council 1879-86; Local Sec. 1879). Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1901. ‡Sorley, Robert. The Firs, Partickill, Glasgow.
1888. ‡SORLEY, Professor W. R., M.A. Trinity College, Cambridge.
1903. ‡Soulby, R. M. Sea Holm, Westbourne-road, Birkdale, Lancashire.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1903. §Southall, Henry T. The Graig, Ross, Herefordshire.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1887. ‡*Spencer, F. M. Fernhill, Knutsford.*
1884. ‡Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newbiggin House, Kenton, Newcastle-upon-Tyne.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen-park, Highbury, N.
1894. ‡Spiers, A. H. Gresham's School, Holt, Norfolk.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 107 Sloane-street, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1897. §Squire, W. Stevens, Ph.D. Clarendon House, 30 St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. 164 Shoreditch, E.C.
1897. ‡Stafford, Joseph. Morrisburg, Ontario, Canada.
1903. §Stallworthy, Rev. George B. The Manse, Hindhead, Haslemere, Surrey.
1883. *Stanford, Edward, F.R.G.S. 12–14 Long-acre, W.C.

Year of Election.

1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. McGill University, Montreal, Canada
1900. *Stansfield, H., B.Sc. Municipal Technical School, Blackburn.
1899. ‡STARLING, E. H., M.D., F.R.S., Professor of Physiology in University College, London, W.C.
1876. ‡*Starling, John Henry, F.C.S. 32 Craven-street, Strand, W.C.*
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. ‡Stather, J. W., F.G.S. 16 Louis-street, Hull.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven. Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1900. *Stead, J. E., F.R.S. Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 169 Gloucester-terrace, W.
1891. ‡*Steeds, A. P. 15 St. Helen's-road, Swansea.*
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1902. §Stephenson, G. Cuilin, Glasnevin, Dublin.
1901. ‡Steven, William. 420 Sauchiehall-street, Glasgow.
1901. ‡Steven, Mrs. W. 420 Sauchiehall-street, Glasgow.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpill, R.S.O.
1900. ‡STEVENS, FREDERICK (Local Sec. 1900.) Town Clerk's Office, Bradford.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C., M.P. Eltham Court, Eltham, Kent.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
1864. ‡STEWART, CHARLES, M.A., F.R.S., F.L.S., Hunterian Professor of Anatomy and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn-fields, W.C.
1892. ‡*Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.*
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 14 Windsor-terrace West, Kelvinside, Glasgow.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1901. *Stewart, John Joseph, M.A., B.Sc. 35 Stow Park-avenue, Newport, Monmouthshire.
1892. ‡*Stewart, Samuel. Knocknairn, Bagston, Greenock.*
1901. §Stewart, Thomas. St. George's-chambers, Cape Town.
1901. ‡Stewart, Walter, M.A., D.Sc. Gartsherrie, Coatbridge.
1901. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1904. §Stobbs, J. T. Dunelm, Basford Park, Stoke-on-Trent.

Year of
Election.

1901. *Stobo, Thomas. Somerset House, Garelochhead, Dumbartonshire, N.B.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. ‡Stoddart, F. Wallis, F.I.C. Grafton Lodge, Sneyd Park, Bristol.
1898. *Stokes, Professor George J., M.A. Riversdale, Sunday's Well, Cork.
1887. ‡Stone, E. D., F.C.S. Rose Lea, Alderley Edge, Cheshire.
1899. *Stone, Rev. F. J. Radley College, Abingdon.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1876. ‡Stone, Octavius C., F.R.G.S. Rothbury House, Westcliff-gardens, Bournemouth.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1895. *Stoney, Miss Edith A. 30 Ledbury-road, Bayswater. W.
1878. *Stoney, G. Gerald. Oakley, Heaton-road, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. (Pres. A, 1897.) 30 Ledbury-road, Bayswater, W.
1903. *Stopes, Miss Marie, Ph.D., B.Sc. 25 Denning-road, Hampstead, N.W.
1883. ‡Stopes, Mrs. 25 Denning-road, Hampstead, N.W.
1887. *Storey, H. L. Bailrigg, Lancaster.
1884. ‡Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. Woodley Grange, Bradford-on-Avon, Wilts.
1874. ‡*Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.*
1871. *STRACHEY, Lieut.-General Sir RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. (Pres. E, 1875; Council, 1871–75.) 69 Lancaster-gate, Hyde Park, W.
1881. ‡STRAHAN, AUBREY, M.A., F.R.S., F.G.S. (Pres. C, 1904.) Geological Museum, Jermyn-street, S.W.
1863. ‡Straker, John. Wellington House, Durham.
1882. ‡Strange, Rev. Canon Cresswell, M.A. The College, Worcester.
1881. ‡STRANGWAYS, C. FOX, F.G.S. Geological Museum, Jermyn-street, S.W.
1889. ‡Streatfeild, H. S., F.G.S. Ryhope, near Sunderland.
1879. ‡Strickland, Sir Charles W., Bart., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M. 3 Champion-park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the College of Science, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the University of Leeds.
1876. *Stuart, Charles Maddock, M.A. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. 5 Prince's-square, W.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1892. ‡Stuart-Gray, Hon. Morton, M.A., F.G.S. 2 Belford-park, Edinburgh.
1896. ‡Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1885. ‡Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1897. ‡Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. Brinkcliffe Tower, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., D.Sc. University College of Wales, Aberystwyth.

Year of Election.

1902. §Sully, H. J. Avalon House, Priory-road, Clifton, Bristol.
1898. §Sully, T. N. Avalon House, Priory-road, Clifton, Bristol.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. *Sumpner, W. E., D.Sc. Technical School, Suffolk-street, Birmingham.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1903. §Swallow, Rev. R. D., M.A. Chigwell School, Essex.
1881. §SWAN, Sir JOSEPH WILSON, M.A., D.Sc., F.R.S. 58 Holland-park, W.
1897. ‡Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1887. §SWINBURNE, JAMES, M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. 22 Oxford-road, Birkdale, Southport.
1890. ‡SWINHOE, Colonel C., F.L.S. Avenue House, Oxford.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. ‡Sykes, E. R. 3 Gray's Inn-place, W.C.
1902. *Sykes, Miss Ella C. Elcombs, Lyndhurst, Hampshire.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. Kensington House, Pensford, near Bristol.
1902. *Sykes, Major P. Molesworth, C.M.G. Elcombs, Lyndhurst, Hampshire.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1903. §Symington, Howard W. Brooklands, Market Harborough.
1885. ‡SYMINGTON, JOHNSON, M.D., F.R.S., F.R.S.E. (Pres. H, 1903), Professor of Anatomy in Queen's College, Belfast.
1886. ‡Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896. ‡Tabor, J. M. Holmwood, Harringay Park, Crouch End, N.
1898. ‡Tagart, Francis. 199 Queen's-gate, S.W.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1894. ‡Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1904. §Tallack, H. T. Clovelly, Birdhurst-road, South Croydon.
1903. *Tanner, Miss Ellen G. 48 Campden House Court, Gloucester-walk, W.
1890. §TANNER, H. W. LLOYD, D.Sc., F.R.S. (Local Sec. 1891), Professor of Mathematics and Astronomy in University College, Cardiff.
1897. ‡Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G., M.A., F.L.S. University College, W.C.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Broadhayes, Dean Park, Bournemouth.

Year of Election.

1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
1902. ‡Tate, Miss. Rantalard, Whitehouse, Belfast.
1901. ‡Taylor, Benson. 22 Hayburn-crescent, Partick, Glasgow.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. ‡Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. ‡Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. **Taylor, H. A.* *69 Addison-road, Kensington, W.*
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1860. *Taylor, John, M.Inst.C.E., F.G.S. 6 Queen Street-place, E.C.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1899. ‡Taylor, Robert H., Assoc.M.Inst.C.E. 5 Maison Dieu-road, Dover.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1900. ‡Taylor, T. H. Yorkshire College, Leeds.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1901. §Taylor, William. 57 Sparkenhoe-street, Leicester.
1903. ‡Taylor, William. 61 Cambridge-road, Southport.
1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡*Taylor, W. F.* *Bhootan, Whitehorse-road, Croydon, Surrey.*
1894. *Taylor, W. W., M.A. 30 Banbury-road, Oxford.
1901. *Teacher, John H., M.B. 32 Kingsborough-gardens, Glasgow.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. (Pres. C, 1893; Council 1894–1900), Director of the Geological Survey of the United Kingdom. 89 Thurlow Park-road, West Dulwich, S.E.
1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1889. ‡*Tennant, James.* *Saltwell, Gateshead.*
1882. ‡Terrill, William. 42 St. George's-terrace, Swansea.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *THANE, GEORGE DANCER, Professor of Anatomy in University College, London, W.C.
1889. ‡Thetford, The Right Rev. A. T. Lloyd, D.D., Bishop of. North Creake Rectory, Fakenham, Norfolk.
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council 1885–89, 1895–1900.) Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark Hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Penurrig, Builth.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. ‡Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1903. §Thomas, Miss Ethel N. 3 Downe-mansions, Gondar-gardens, West Hampstead, N.W.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.

Year of Election.

1881. ‡THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 86 Breakspears-road, Brockley, S.E.
1880. *Thomas, Joseph William, F.C.S. Overdale, Shortlands, Kent.
1899. *Thomas, Mrs. J. W. Overdale, Shortlands, Kent.
1902. §Thomas, Miss M. B. 200 Bristol-road, Birmingham.
1904. §Thomas, Northcote W. 7 Coptic-street, W.C.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1898. ‡Thomas, Rev. U. Bristol School Board, Guildhall, Bristol
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1904. §Thomas William. Bryn-heulog, Merthyr-Tydfil.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡THOMPSON, D'ARCY W., B.A., C.B., Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1904. *Thompson, G. R., B.Sc., Professor of Mining in the University of Leeds.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1897. ‡Thompson, J. Barclay. 37 St. Giles's, Oxford.
1891. ‡Thompson, J. Tatham, M.B. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Cheshire.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S. (Council 1897–99), Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.
1883. *Thompson, T. H. Oldfield Lodge, Gray-road, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., D.Sc., King's Professor of Institutes of Medicine (Physiology) in Trinity College, Dublin. 14 Hatch-street, Dublin.
1896. ‡Thompson, W. P. 6 Lord-street, Liverpool.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1894. ‡THOMSON, ARTHUR, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1891. ‡Thomson, John. 70A Grosvenor-street, W.
1896. ‡*Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.*
1890. ‡THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡THOMSON, J. J., M.A., D.Sc., F.R.S. (Pres. A, 1896; Council 1893–95), Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S. (Council 1895–1901), Professor of Chemistry in King's College, London. 85 Addison-rd., W.

Year of Election.

1902. ‡Thomson, J. Stuart. Marine Biological Laboratory, Plymouth.
1901. §Thomson, Dr. J. T. Kilpatrick. 148 Norfolk-street, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1897. ‡Thorburn, James, M.D. Toronto, Canada.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1898. §Thornton, W. M. The Durham College of Science, Newcastle-on-Tyne.
1902. ‡Thornycroft, Sir John I., F.R.S., M.Inst.C.E. Eyot Villa, Chiswick Mall, W.
1883. ‡Thorowgood, Samuel. Castle-square, Brighton.
1903. §Thorp, Edward. 87 Southbank-road, Southport.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. 37 Pleasant-street, New Brighton, Cheshire.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. ‡Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.
1871. ‡THORPE, T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1890; Council 1886–92), Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §THRELFALL, RICHARD, M.A., F.R.S. 30 George-road, Edgbaston, Birmingham.
1896. §Thrift, William Edward, M.A., Professor of Natural and Experimental Philosophy in the University of Dublin. 80 Grosvenor-square, Rathmines, Dublin.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 175 Banbury-road, Oxford.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., Treas.C.S. (Pres. B, 1888, Council 1898–1904), Professor of Chemistry in the Royal College of Science, London. The Oaks, Northwood, Middlesex.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Liverpool.
1899. ‡Tims, H. W. Marett, B.A., M.D., F.L.S. 10 Bateman-street, Cambridge.
1902. §Tipper, Charles J. R., B.Sc. 21 Greenside, Kendal.
1900. §Tocher, J. F., F.I.C. 5 Chapel-street, Peterhead, N.B.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.
1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.
1897. ‡Todhunter, James. 85 Wellesley-street, Toronto, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1896. ‡*Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.*
1887. ‡Tonge, James, F.G.S. 24 Hampton-road, Southport.
1865. ‡*Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.*
1873. *Tookey, Charles, F.C.S. Portland Hotel, Great Portland-street, W.
1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.

Year of Election.

1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.
1901. ‡Townsend, J. S. E., M.A., F.R.S., Professor of Physics in the University of Oxford. New College, Oxford.
1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D., Provost of Trinity College, Dublin. Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1868. ‡TRAQUAIR, RAMSAY H., M.D., LL.D., F.R.S., F.G.S. (Pres. D, 1900), Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1902. ‡Travers, Ernest J. Dunmurry, Co. Antrim.
1891. ‡*Trayes, Valentine. Maindell Hall, Newport Monmouthshire.*
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
1887. *Trench-Gascoigne, Mrs. F. R. Lotherton Hall, Parlington, Aberford, Leeds.
1903. ‡Trenchard, Hugh. The Firs, Clay Hill, Enfield.
1889. ‡*Trendell, Edwin James, J.P. Abbey House, Abingdon, Berkshire.*
1884. ‡Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1871. ‡TRIMEN, ROLAND, M.A., F.R.S., F.L.S., F.Z.S. 26 Campden-grove, Campden Hill, W.
1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.
1902. §Tristram, Rev. J. F., M.A., B.Sc. 160 Cecil-street, Moss Side, Manchester.
1884. *Trotter Alexander Pelham. 8 Richmond-terrace, Whitehall, S.W.
1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *TROUTON, FREDERICK T., M.A., D.Sc., F.R.S., Professor of Physics in University College, W.C.
1898. §Trow, Albert Howard. Glanhafren, 50 Clive-road, Penarth.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, Sir J. Batty, M.D., M.P. Cupar, Fifeshire.
1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B. Ottawa, Canada.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1901. §Turnbull, Robert, B.Sc. Department of Agriculture and Technical Instruction, Dublin.
1901. ‡Turner, A. Crosbie. 65 Bath-street, Glasgow.
1893. §TURNER, DAWSON, M.B. 37 George-square, Edinburgh.
1894. *TURNER, H. H., M.A., D.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C., Professor of Metallurgy in the University of Birmingham. 35 Wellington-road, Edgbaston, Birmingham.
1863. *TURNER, Sir WILLIAM, K.C.B., LL.D., D.C.L., F.R.S, F.R.S.E. (PRESIDENT, 1900; Pres. H, 1889, 1897), Principal of the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.
1890 *Turpin, G. S., M.A., D.Sc. High School, Nottingham.

Year of Election.

1886. **Twigg, G. H.* *56 Claremont-road, Handsworth, Birmingham.*
1898. ‡Twiggs, H. W. 65 Victoria-street, Bristol.
1899. ‡Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1888. ‡Tyack, Llewelyn Newton. University College, Bristol.
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council 1896–1902), Professor of Anthropology in the University of Oxford. Museum House, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. ‡Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1903. ‡Underwood, Captain J. C. 60 Scarisbrick New-road, Southport.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick, W.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99.) 7 Palace Gate-mansions, Kensington, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1898. ‡Usher, Thomas. 3 Elmgrove-road, Cotham, Bristol.
1902. §Ussher, R. J. Cappagh House, Cappagh, Co. Waterford.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1896. ‡Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1903. §Vallack, Edmund. 5 St. Michael's-terrace, Stoke, Devonport.
1888. ‡*Vallentin, Rupert.* *18 Kimberley-road, Falmouth.*
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, N.
1865. *VARLEY, S. ALFRED. Arrow Works, Jackson-road, Holloway, N.
1903. ‡Varwell, H. B. 2 Pennsylvania Park, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, W.
1895. §Vaughan, D. T. Gwynne. Botanical Laboratory, The University, Glasgow.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., D.Sc., F.R.S. 20 Bradmore-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1904. *Vernon, H. M., M.A., M.D. 3 Bevington-road, Oxford.
1896. *Vernon, Thomas T. Wyborne Gate, Birkdale, Southport.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Carlisle Lodge, Rickmansworth.
1899. *VINCENT, Professor SWALE, M.B. Physiological Laboratory, University of Manitoba, Winnipeg, Canada.

Year of Election.

1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1902. §Vinycomb, T. B. Riverside, Holywood, Co. Down.
1891. ‡*Vivian, Stephen. Llantrisant.*
1904. §Volterra, Professor Vito. Regia Universita, Rome.

1904. §Wace, A. J. B. Pembroke College, Cambridge.
1886. *Wackrill, Samuel Thomas, J.P. 38 Portland-street, Leamington.
1902. ‡Waddell, Rev. C. H. The Vicarage, Saintfield.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1900. ‡Waddington, Dr. C. E. 2 Marlborough-road, Manningham, Bradford.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T., F.R.S., F.L.S. Arnold House, Bass-street, Derby.
1900. ‡*Wagstaff, C. J. L., B.A. 8 Highfield-place, Manningham, Bradford.*
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1902. ‡Wainwright, Joel. Finchwood, Marple Bridge, Stockport.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. ‡*Waite, J. W. The Cedars, Bestcot, Walsall.*
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1884. ‡Waldstein, Professor C., M.A., Ph.D. King's College, Cambridge.
1891. ‡*Wales, H. T. Pontypridd.*
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡WALFORD, EDWIN A., F.G.S. 21 West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. Downside, Whitchurch, Tavistock.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Ulcombe Place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901. *Walker, Archibald, M.A., F.I.C. 8 Crown-terrace, Glasgow.
1897. *WALKER, B. E., F.G.S. (Local Sec. 1897). Canadian Bank of Commerce, Toronto, Canada.
1883. ‡Walker, Mrs. Emma. 13 Lendal, York.
1904. §Walker, E. R. 19 Roe-lane, Southport.
1891. ‡Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1897. ‡Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A., D.Sc., F.R.S., F.R.A.S. Meteorological Office, Simla, India.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. ‡Walker, Horace. Belvidere-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 19 Springfield, Dundee.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. Bloomfield-crescent, Bath.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 7 Cambridge-road, Southport.
1895. ‡WALKER, WILLIAM G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1896. ‡Walker, W. J. D. Glenhanna, Laurencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. (Pres. D, 1876; Council 1870–72.) Broadstone, Wimborne, Dorset.

Year of Election.

1897. ‡Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1901. ‡Wallace, William, M.A., M.D. 25 Newton-place, Glasgow.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. 32 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston, Birmingham.
1894. *WALMISLEY, A. T., M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1903. ‡Walsh, W. T. H. Toynbee Hall, Whitechapel, E.
1895. ‡WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1902. *Walter, Miss L. Edna. 38 Woodberry-grove, Finsbury Park, N.
1904. *Walters, William, jun. Albert House, Newmarket.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1904. §Ward, A. H. M., B.A. Lenoxvale, Belfast.
1887. ‡WARD, A. W., M.A., Litt.D., Master of Peterhouse, Cambridge.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, D.Sc., F.R.S., F.L.S. (Pres. K, 1897; Council 1890–97), Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.
1887. ‡WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. 4 Chepstow-mansions, Chepstow-place, Bayswater, W.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Standard Underground Cable Co., 16th-street, Pittsburg, Pennsylvania, U.S.A.
1878. ‡WARINGTON, ROBERT, F.R.S., F.C.S. High Bank, Harpenden, St. Albans, Herts.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1887. ‡WARREN, Lieut.-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887.) Athenæum Club, S.W.
1898. ‡*Warrington, Arthur W. University College, Aberystwyth.*
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *WATERHOUSE, Major-General J. Oak Lodge, Court-road, Eltham, Kent.
1904. §Waters, A. H., B.A. 48 Devonshire-road, Cambridge.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1900. §Waterston, David, M.D. 23 Colinton-road, Edinburgh.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.

Year of Election.

1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. *Watson, Arnold Thomas, F.L.S. Southwold, Tapton Crescent-road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville-road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, W.C.
1892. §Watson, G., Assoc.M.Inst.C.E. Stonegate, Pool-in-Wharfedale, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. P.O. Box 317, Johannesburg, South Africa.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1894. *WATSON, Professor W., D.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. The Lea, Corstorphine, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. The Crofts, Seascale, Cumberland.
1882. ‡Watt, Alexander. 29 Grange Mount, Claughton, Birkenhead.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1901. §Watt, Henry Anderson. Ardenslate House, Hunter's Quay, Argyllshire.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. The Red House, Bemerton, Salisbury.
1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near Penistone.
1896. ‡Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. 166 Venner-road, Sydenham, S.E.
1883. *WATTS, W. W., M.A., M.Sc., F.R.S., Sec.G.S. (Pres. C, 1903; Council 1902–), Assistant Professor of Geology in the University of Birmingham. Holmwood, Bracebridge-road, Sutton Coldfield.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡*Webb, George. 5 Tenterden-street, Bury, Lancashire.*
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1891. §Webber, Thomas. The Laurels, 83 Newport-road, Roath, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Jahnstrasse 5, Karlsruhe.
1903. §Weekes, R. W., A.M.Inst.C.E. 65 Hayes-road, Bromley, Kent.
1889. ‡Weeks, John G. Bedlington.
1890. *WEISS, F. ERNEST, D.Sc., F.L.S., Professor of Botany in the Victoria University, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, S.W.
1902. ‡Welch, R. J. 49 Lonsdale-street, Belfast.
1894. †Weld, Miss. Conal More, Norham-gardens, Oxford.
1876. *WELDON, Professor W. F. R., M.A., F.R.S., F.L.S. (Pres. D, 1898.) The Museum, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1897. ‡Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill-buildings, E.C.

Year of
Election.

1881. ‡Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894. ‡Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Roslyn, Walland's Park, Lewes.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. †Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1898. ‡West, Charles D. Imperial University, Tokyo, Japan.
1853. †West, Leonard. Summergangs Cottage, Hull.
1900. §West, William, F.L.S. 26 Woodville-terrace, Horton-lane, Bradford.
1903. §Westaway, F. W. 1 Pemberley-crescent, Bedford.
1897. ‡Western, Alfred E. 36 Lancaster-gate, W.
1882. *Westlake, Ernest, F.G.S. Fordingbridge, Salisbury.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1900. ‡Wethey, E. R., M.A., F.R.G.S. 4 Cunliffe-villas, Manningham, Bradford.
1904. §Weymouth, E. S., M.A. 27 Southampton-street, Strand, W.C.
1885. *WHARTON, Admiral Sir W. J. L., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S. (Pres. E, 1894; Council 1890-91.) Florys, Prince's-road, Wimbledon Park, Surrey.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1893. *WHETHAM, W. C. D., M.A., F.R.S. Upwater Lodge, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. Hammerwood Lodge, East Grinstead, Sussex.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council 1890-96.) 3 Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡*White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.*
1886. ‡WHITE, A. SILVA, Hon. F.R.S.G.S. (ASSISTANT SECRETARY.) 63 St. James's-street, S.W.
1898. ‡White, George. Clare-street House, Bristol.
1904. §White, H. Lawrence, B.A. 2 St. Margaret's-terrace, Cheltenham.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. 6 Southwell-gardens, S.W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. †White, R. 'Gazette' Office, Montreal, Canada.

Year of
Election.

1898. ‡White, Samuel. Clare-street House, Bristol.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 20 Hillersdon-avenue, Church-road, Barnes, S.W.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. (Pres. G, 1899; Council 1897–1900). Cedarcroft, Putney Heath, S.W.
1904. §WHITEHEAD, J. E. L., M.A. (Local Sec. 1904). Guildhall, Cambridge.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 5 Bagnall-street, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1900. ‡Whitley, E. N. Heath Royde, Halifax.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Hyde Park, Leeds.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1897. ‡WHITTAKER, E. T., M.A. Trinity College, Cambridge.
1901. §Whitton, James. City Chambers, Glasgow.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. Alpha Villa, Southwood, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1883. ‡Whitworth, James. 36 Lethbridge-road, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1897. ‡Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡*Wiggin, Henry A. The Lea, Harborne, Birmingham.*
1896. ‡Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *WILBERFORCE, L. R., M.A., Professor of Physics in the University of Liverpool.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, D.Sc., D.C.L., F.R.S. The Hurst, Alderley Edge, Cheshire.
1896. ‡Wildermann, Meyer. Royal Institution, Albemarle-street, W.
1904. §Wilkinson, Mrs. Caroline. Dringhouses Manor, York.
1900. §Wilkinson, J. B. Holme-lane, Dudley Hill, Bradford.
1892. ‡Wilkinson, Rev. J. Frome., M.A. Barley Rectory, Royston, Herts.
1886. **Wilkinson, J. H. Elmhurst Hall, Lichfield.*
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡*Willans, J. W. Kirkstall, Leeds.*
1872. ‡WILLETT, HENRY (Local Sec. 1872). Arnold House, Brighton.
1903. ‡Willett, John E. 3 Park-road, Southport.
1894. ‡Willey, Arthur, D.Sc., F.R.S. The Museum, Colombo, Ceylon.
1904. *Williams, Miss Antonia. 6 Sloane-gardens, S.W.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1888. ‡Williams, James. Bladud Villa, Entry Hill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Ramalho, Oatlands Park, Weybridge.
1883. *Williams, Mrs. J. Davies. 5 Chepstow-mansions, Bayswater, W.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke-vale, Clifton, Bristol.

Year of Election.

1901. *Williams, Miss Mary. 6 Sloane-gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡ *Williams, R. Price. 28 Compayne-gardens, West Hampstead, N.W.*
1883. ‡Williams, T. H. 27 Water-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. University College, Sheffield.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1894. *Williamson, Mrs. Janora. Ardoyne, Birkbeck-road, Muswell Hill, N.
1895. ‡WILLINK, W. (Local Sec. 1896). 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., F.L.S., Director of the Royal Botanical Gardens, Peradeniya, Ceylon.
1896. ‡WILLISON, J. S. (Local Sec. 1897). Toronto, Canada.
1859. *Wills, The Hon. Sir Alfred. Saxholm, Basset, Southampton.
1898. ‡Wills, H. H. Barley Wood, Wrington, R.S.O., Somerset.
1899. §Willson, George. 12 St. Leonard's-terrace, Streatham, S.W.
1899. §Willson, Mrs. George. 12 St. Leonard's-terrace, Streatham, S.W.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1901. ‡Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1904. §Wilson, Charles John. Deanfield, Hawick, Scotland.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1903. §Wilson, C. T. R., M.A., F.R.S. Sidney Sussex College, Cambridge.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. (Pres E, 1874, 1888.) The Athenæum Club, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1904. §Wilson, David, M.D. Grove House, Paddock, Huddersfield.
1900. *Wilson, Duncan R. Menethorpe, Malton.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1903. §Wilson, George. The University, Leeds.
1874. *Wilson, George Orr. 20 Berkeley-street, W.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1895. ‡Wilson, Dr. Gregg. Queen's College, Belfast.
1901. §Wilson, Harold A. Trinity College, Cambridge.
1902. *Wilson, Harry, F.I.C. 146 High-street, Southampton.
1883. *Wilson, Henry, M.A. Farnborough Lodge, Farnborough, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall-gate, Doncaster.
1865. ‡WILSON, Ven. Archdeacon JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Hillside House, Avon-road, Walthamstow, N.E.
1901. §Wilson, Mrs. Mary R., M.D. Ithaca, New York, U.S.A.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.

Year of Election.

1892. §Wilson, T. Stacey, M.D. 27 Wheeley's-road, Edgbaston, Birmingham.
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., D.Sc., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1904. §Wimperis, J. T. 37 Half Moon-street, W.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., President of Queen's College, Cork.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864.) 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, Right Hon. E. R., M.P. 56 Chester-square, S.W.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–1903.) 21 Delahay-street, Westminster, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1898. ‡Wollaston, G. H. Clifton College, Bristol.
1884. ‡Womack, Frederick, M.A., B.Sc., Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. Bedford College, Baker-street, W.
1883. ‡Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1901. *Wood, Miss Ethel M. 3 Shorncliffe-road, Folkestone.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, W.C.; and 16 Leinster-square, Bayswater, W.
1883. *Wood, J. H. 21 Westbourne-road, Birkdale, Lancashire.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, T. Baileyfield, Portobello, Edinburgh.
1904. §Wood, T. B., M.A. Caius College, Cambridge.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James. 266 George-street, Glasgow.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1853. *Woodall, J. W., M.A. 5 Queen's-mansions, Victoria-street, S.W.
1899. *Woodcock, Mrs. E. M. Lohaghur, *via* Solat, Panighatta P. O., Siliguri, North Bengal, India.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡ *Woodd, Arthur B. Woodlands, Hampstead, N.W.*
1896. §WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1904. §Woodrow, John. Berryknowe, Meikleriggs, Paisley.
1904. §Woods, Henry, M.A. St. John's College, Cambridge.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S. (Council 1903–), Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. 127 Metchley-lane, Harborne, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94.) 129 Beaufort-street, Chelsea, S.W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1894. *Woodward, John Harold. 8 Queen Anne's-gate, Westminster, S.W.

Year of Election.

1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith. South Collingham, Newark.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. ‡Worth, J. T. Oakenrod Mount, Rochdale.
1904. §Worthington, A. M., C.B., F.R.S., Professor of Physics in the Royal Naval Engineering College, Devonport. Mohuns, Tavistock.
1855. *Worthington, Rev. Alfred William, B.A. Old Swinford, Stourbridge.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Baslow, Derbyshire.
1883. *Wright, Rev. Arthur, D.D. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1902. §Wright, John. The White House, Burns-street, Nottingham.
1874. ‡Wright, Joseph, F.G.S. 4 Alfred-place, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. University College, Toronto, Canada.
1904. §Wright, R. T. Goldieslie, Trumpington, Cambridge.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1903. §Wright, William. The University, Birmingham.
1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.P., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1898. ‡Wrong, Professor George M. The University, Toronto, Canada.
1902. ‡Wyatt, G. H. 1 Maurice-road, St. Andrew's Park, Bristol.
1897. ‡Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1901. §Wylie, Alexander. Kirkfield, Johnstone, N.B.
1902. ‡Wylie, John. 2 Mafeking-villas, Whitehead, Belfast.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Plas-yn-Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.
1899. ‡WYNNE, W. P., D.Sc., F.R.S., Professor of Chemistry in University College, Sheffield. 106 Whitham-road, Sheffield.

1875. ‡Yabbicom, Thomas Henry. 23 Oakfield-road, Clifton, Bristol.
1901. *Yapp, R. H., M.A., Professor of Botany in University College, Aberystwyth.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1904. §Young, Alfred. Selwyn College, Cambridge.
1891. §Young, Alfred C., F.C.S. 53A Algiers-road, Ladywell, S.E.
1886. *YOUNG, A. H., M.B., F.R.C.S. (Local Sec. 1887), Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. University College, Sheffield.

Year of
Election.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. *Young, John. 2 Montague-terrace, Kelvinside, Glasgow.
1896. ‡*Young, J. Denholm.* 88 *Canning-street, Liverpool.*
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1901. ‡Young, Robert M., B.A. Rathvarna, Belfast.
1883. *Young, Sydney, D.Sc., F.R.S. (Pres. B, 1904), Professor of Chemistry in the University of Dublin. 12 Raglan-road, Dublin.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1890. †Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1901. ‡Young, William Andrew. Milburn House, Renfrew.
1903. §Yoxall, J. H., M.P. 67 Russell-square, W.C.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. 3909 Locust-street, Philadelphia, U.S.A.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. 50 quai des Pêcheurs, Liège, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette-place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. XVIII. Haizingergasse 26, Vienna.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D., LL.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Kristiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim, Germany.
1894. Emile Cartailhac. 5 rue de la Chaîne, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. 7 rue Cuvier, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, D.C., U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1901. Dr. Yves Delage. Paris.
1872. Professor G. Dewalque. 17 rue de la Paix, Liège, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 4 Quai Marcellis, Liège, Belgium.

Year of Election.

1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor H. Elster. Wolfenbüttel, Germany.
1894. Professor T. W. W. Engelmann, D.C.L. Neue Wilhelmstrasse 15, Berlin, N.W.
1892. Professor Léo Errera. 38 rue de la Loi, Brussels.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Alteurekring N. 19b, Braunschweig, Germany.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden, Netherlands.
1894. Professor Léon Fredericq. Rue de Pitteurs 20, Liège, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Dorotheen Strasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1866. Dr. Gaudry. 7 bis rue des Saints Pères, Paris.
1901. Professor Dr. H. Geitel. Wolfenbüttel, Germany.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, U.S.A.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, U.S.A.
1870. William Gilpin. Denver, Colorado, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1893. Professor Paul Heger. Rue de Drapiers 23, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R.I., U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1867. Dr. J. Janssen, LL.D. L'Observatoire, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. 116 rue de Carouge, Geneva, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. 32 East Preston-street, Baltimore, U.S.A.
1887. Professor C. Julin. 153 rue de Fragnée, Liège.
1876. Dr. Giuseppe Jung. Bastions Vittoria 31, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokyo, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 186-7, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Marchstrasse 25B, and Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1894. Maxime Kovalevsky. 13 Avenue de l'Observatoire, Paris, France.

Year of Election.

1887. Professor W. Krause. Knesebeckstrasse, 17/I, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelmstrasse 108, Breslau.
1887. Professor J. W. Langley. 77 Cornell-street, Cleveland, Ohio, U.S.A.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution, Washington, U.S.A.
1872. M. Georges Lemoine. 76 rue Notre Dame des Changes, Paris.
1901. Professor Philipp Lenard. Kiel.
1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
1877. Dr. M. Lindemann. Sennorrstrasse 62, II, Dresden.
1887. Professor Dr. Georg Lunge. Universität, Zurich.
1871. Professor Jacob Lüroth. Mozartstrasse 10, and Universität, Freiburg-in-Breisgau, Germany.
1894. Professor Dr. Otto Maas. Universität, Munich.
1887. Dr. Henry C. McCook. 3700 Chestnut-street, Philadelphia, U.S.A.
1867. Professor Mannheim. 1 Boulevard Beauséjour, Paris.
1887. Dr. C. A. Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 rue de l'Université, Paris.
1887. Professor D. I. Mendeléeff, D.C.L. Université, St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
1894. Professor G. Mittag-Leffler. Djuvsholm, Stockholm.
1893. Professor H. Moissan. The Sorbonne, Paris (7 Rue Vauquelin).
1877. Professor V. L. Moissenet. 15 rue du Château Paillot, Chaumont, Haute Marne, France.
1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III/3.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1897. Professor E. W. Morley, LL.D. Adelbert College, Cleveland, Ohio, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padova, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. 1620 P-street, Washington, D.C., U.S.A.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, U.S.A.
1890. Maffeo Pantaleoni. 20 Route de Malagnou, Geneva.
1895. Professor F. Paschen. Universität, Tübingen.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a/Main, Germany.
1901. Hofrath Professor A. Penck. Marokkanergasse 12, Vienna.
1890. Professor Otto Pettersson. Stockhoms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1886. Professor F. W. Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.

Year of Election.

1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1897. Professor Dr. C. Richet. 15 rue de l'Université, Paris, France.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin, W.
1896. Dr. van Rijckevorsel. Parklaan 3, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, U.S.A.
1895. Professsr Karl Runge. Kaiser Wilhelmstrasse 5, Kirchrode, bei Hannover.
1901. Gen.-Major Rykatchew. Central Physical Observatory, St. Petersburg.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands, de Bilt, near Utrecht.
1887. Professor H. Graf Solms. Botanischer Garten, Strassburg.
1887. Ernest Solvay. 25 rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd-street, Cincinnati, Ohio, U.S.A.
1889. Professor G. Stefanescu. Strada Verde 8, Bucharest, Roumania.
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